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DIFFERENCES IN FREQUENCY OF CELLULAR ANTIGENS IN TWO BREEDS OF DAIRY CATTLE[1]

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ALTHOUGH consistent breed differences among domestic animals are accepted as being essentially genetic, there has been little progress in the identification of the various genes responsible for these differences. The complex genetic nature of most of the morphological and physiological characteristics distinguishing the breeds, the relatively small number of known Mendelian units in domestic animals, and the fact that most of the variations having a simple genetic basis are abnormalities of very low frequency in any breed have combined to make studies of this nature impossible. Lush (1943) presents the modern concept that characteristic breed differences are largely the result of contrasting gene frequencies among factors shared by the breeds. He concludes, however, that the difficulties of obtaining gene-frequency estimates, except for a few genes with individually conspicuous effects, make it likely that "for a long time to come . . . the practical description of a breed will consist mainly of its averages, or 'type' in traits which do not lend themselves readily to numerical averaging, with a few sketchy semi-quantitative comments about its variability in those features."

Anthropological applications of differences among human races in the frequencies of the antigens of the blood cells have been discussed extensively by Wiener (1943). Investigations of this nature are accepted as a satisfactory approach to the genetic nature of racial differences. Material is now at hand for a similar analysis of breed differences in cattle. If we accept Dobzhansky's discussion (1941) of the genetic conception of race, it would seem that the problems of genetic differences among races in natural populations and those of breed differences in domestic animals are similar.

During the past few years thirty antigens of the red blood cells of cattle have been reported and their inheritance analyzed (Ferguson, 1941; Ferguson, Stormont and Irwin, 1942). Each of these antigens has been shown to

[1] From the Departments of Genetics (Paper No. 333) and Veterinary Science, University of Wisconsin, in cooperation with the Bureau of Animal Industry, United States Department of Agriculture. This investigation was supported in part by The Rockefeller Foundation, the American Guernsey Cattle Club and the Holstein-Friesian Association of America.

[2] The authors wish to acknowledge extensive contributions to the data by Dr. L. C. Ferguson, who is now in military service. Appreciated assistance in the tabulation and analysis was given by Mr. Richard Pierce and Miss Elizabeth Lingard. A number of dairy cattle breeders, among them Mr. Howard Clapp, representing Pabst Farms, Oconomowoc, Wisconsin and Mr. Noble Heany, Glen Ellyn, Illinois, provided blood samples from animals in their herds for the genetic investigations.

behave in inheritance as if controlled by a single gene. However, more recent work (to be presented in later papers) on the genetic relationships between different antigens has indicated that many of them are produced either by genes in multiple allelic series or by series of very closely linked genes, and has further suggested that a single allele or complex may govern the production of two or more immunologically distinct antigens. For these reasons the number of gene loci marked by these antigens may be much smaller than was at first thought to be the case, and a "gene frequency" calculated from the frequency of a particular antigen would not always be independent of the frequency of other antigens. Furthermore, a gene frequency so calculated may represent the combined frequencies of several alleles rather than of a single gene.

In spite of these complications the clear-cut genetic determination of these antigens provides a unique opportunity for an analysis of one sort of inherited breed difference.

Methods and Materials

The method of preparing reagents to detect unit antigens in cattle blood was discussed in detail by Ferguson (1941) and presented in illustrated form by Stormont and Cumley (1943). Briefly, it involves the production in rabbits or cows of antisera against the cells of particular donors, and the testing of these immune sera against a variety of cattle bloods for their ability to hemolyze a suspension of cattle erythrocytes. Fresh or fresh-frozen rabbit serum containing no detectable antibodies against cattle blood cells is used as a source of complement in the hemolytic system. Complex antisera are fractionated by the absorption technique, and reagents are prepared identifying single antigens in the test cells. Once a reagent has been shown to react only with cells containing a particular antigen, the antigen identified by this reagent is assigned a symbol (*e.g.*, **A, S** or **A′**—no relationship between antigens **A** and **A′** is implied in this nomenclature) and a large number of animals is tested for the presence or absence of the antigen in their blood cells. Duplicate reagents prepared from antisera obtained from independent transfusions are available for many of the antigens and were used in most of the tests.

The breed samples upon which this analysis was based included 569 Guernseys and 513 Holsteins, representing a fair cross-section of each breed from nearly all sections of the United States. As the samples comprised considerable numbers of progeny from certain tested bulls, the average relationship of the animals within each breed sample was probably somewhat higher than for the breed as a whole.

Not all animals were tested for all antigens reported to date; many of the

characters were discovered during the period covered by the tests. Furthermore, several of the reagents occasionally gave questionable reactions, so that it was not always possible to decide, without a further check than time permitted, whether an animal had the antigen identified by the reagent. These questionable reactions were rare and are not included in the calculations of breed frequencies of the antigens.

Although individuals representing a number of other breeds were tested, these data are not numerically sufficient for comparison.

Results and Discussion

The number of animals with or without, and the percentage incidence of the antigens in each breed, are given in table 1. The incidence ranges in Guernseys from 87.6% having **A** to 3.2% having **U**, and in Holsteins from 77.5% having **H′** to only 1% having **P**. Nine of the 30 antigens (**A, B, C, E, G, S, W, Z,** and **G′**) are above the 50% frequency level in Guernseys, while only five (**C, Y, Z, F′** and **H′**) are above this level in Holsteins. There is a tendency for the relative position of an antigen on the frequency scale in one breed to agree with its relative position in the other, as shown by the correlation coefficient ($r = .61 \pm .12$) for the paired values of percentage incidence.

The analysis of breed differences is not based on the distributions of percentage incidence, but on chi-square tests for homogeneity of the observed numbers of positive and negative individuals in the two samples, in the manner described by Fisher (1938). For example, 497 of 567 Guernseys tested for **A** possessed this antigen, while only 234 of 508 Holsteins tested for **A** possessed it. The chi-square test permits the conclusion that, in so far as these samples are representative of their respective breeds, it is highly improbable ($p < .01$) that the incidence of **A** is the same in Guernseys as it is in Holsteins. On the other hand, the incidence of **U**, for example, appears to be higher in Holsteins than in Guernseys. The observed difference in incidence of antigen **H** ($x^2 = 0.45$; $p = .5$), however, would be expected to be exceeded in about half of the samples drawn from a single homogeneous population; it may be concluded therefore that there is no significant difference between Guernseys and Holsteins in the frequency of **H.**

A summary of the breed comparisons for all thirty antigens reported to date is included in table 1. It is evident that the majority of these antigens are more frequent in Guernseys than in Holsteins. Eighteen of them, **A, B, C, E, G, I, J, K, P, Q, S, T, W, X, Z, C′, E′** and **G′**, fall into this class; the probability of obtaining so marked a difference in frequency as a result of chance alone in each of these cases (except for **J**) is less than .01. The probability that the difference in the frequency of **J** is the result of chance alone lies between .02 and .01. Seven of the characters (**H, M, N, O, R, V** and

A′) show no significant difference in frequency between the two breeds. Only five (U, Y, D′, F′ and H′) are more frequent in Holsteins; the probability in each of these that the differences result from chance alone is less than .01.

No antigen reported to date serves by itself to distinguish one breed from the other, since each of the thirty antigens occurs in both breeds. The breed differences in blood type are statistical in nature, based on differences in antigen frequency. Because 18 of these antigens are considerably more frequent in Guernseys than in Holsteins, while only five are more frequent in Holsteins, the "typical" Guernsey may be said to possess more antigens of those so far detectable than does the "typical" Holstein. Some Guernseys, however, have fewer of these antigens than do most Holsteins, and some Holsteins possess more of the antigens than do many Guernseys. It should be emphasized that these observations are necessarily based on the antigens reported to date, and it is clearly possible that a number of cellular characters more frequent in Holsteins than in Guernseys and others more frequent in Guernseys may yet be discovered. In this connection it is pertinent to note that, since almost all the immune sera now in use were produced by transfusions between grade Holsteins, the selective nature of the immunological technique of discovering "new" antigens, mentioned below, may have been responsible, at least in part, for the fact that the majority of the antigens so far detected are more frequent in Guernseys than in Holsteins.

In spite of the qualitative identity in the antigens found in Holsteins and Guernseys, each breed as a whole clearly constitutes a distinct population. The question of how this contrast arose cannot be answered here. These characters could not have been subjected directly to selection by breeders, and only indirectly in so far as the presence or absence of particular antigens may be associated with morphological or physiological characteristics. No such association has been noted to date, but no comprehensive search in this direction has been possible as yet. Present antigenic breed differences probably rest either on a difference in antigen frequencies in the populations from which these groups developed, or on a differential drift in gene frequencies after divergence, or on both of these factors.

On first consideration it may appear that this material is well adapted to a study of the factors (mutation pressure, population size, selection pressure, migration pressure, etc., after Wright, Fisher, Haldane and others) affecting the genetic structure of these populations. Certain complications, however, dictate a postponement of such consideration. Since a large number of distinct antigens can be assumed to be segregating within this species, the detection of particular antigens, at least in these early stages of the work, becomes a matter of sampling, and the probability of discovery of an antigen

TABLE 1. ANTIGEN FREQUENCIES IN HOLSTEIN-FRIESIAN AND GUERNSEY CATTLE

Antigen	Guernsey				Holstein				Breed showing higher* frequency of antigen
	Total tested	Antigen absent	Antigen present	% having antigen	Total tested	Antigen absent	Antigen present	% having antigen	
A	567	70	497	87.6	508	274	234	46.1	Guernsey
B	567	223	344	60.7	511	294	217	42.5	Guernsey
C	567	221	346	61.0	510	246	264	51.8	Guersney
E	568	271	297	52.3	502	297	205	40.8	Guernsey
G	565	252	313	55.4	512	287	225	43.9	Guernsey
H	561	501	60	10.7	508	447	61	12.0	N.S.D.**
I	569	308	261	45.9	513	485	28	5.4	Guernsey
J	556	330	226	40.6	487	326	161	33.0	Guernsey***
K	542	302	240	44.3	465	428	37	8.0	Guernsey
M	499	391	108	21.6	446	359	87	19.5	N.S.D.
N	508	392	116	22.8	436	321	115	26.4	N.S.D.
O	560	362	198	35.4	448	287	161	35.9	N.S.D.
P	555	529	26	4.7	480	475	5	1.0	Guernsey
Q	551	480	71	12.9	477	467	10	2.1	Guernsey
R	443	392	51	11.5	409	359	50	12.2	N.S.D.
S	506	173	333	65.8	434	362	72	16.6	Guernsey
T	449	361	88	19.6	428	411	17	4.0	Guernsey
U	408	395	13	3.2	390	345	45	11.5	Holstein
V	405	302	103	25.4	389	293	96	24.7	N.S.D.
W	401	122	279	69.6	390	255	135	34.6	Guernsey
X	406	331	75	18.5	386	345	41	10.6	Guernsey
Y	406	257	149	36.7	400	191	209	52.2	Holstein
Z	409	68	341	83.4	411	192	219	53.3	Guernsey
A′	403	284	119	29.5	391	253	138	35.3	N.S.D.
C′	376	291	85	22.6	375	320	55	14.7	Guernsey
D′	377	308	69	18.3	293	189	104	35.5	Holstein
E′	365	183	182	49.9	378	271	107	28.3	Guernsey
F′	380	227	153	40.3	377	176	201	53.3	Holstein
G′	88	31	57	64.8	314	179	135	43.0	Guernsey
H′	91	49	42	46.2	325	73	252	77.5	Holstein

* Unless otherwise noted, $p < .01$ (chi-square test—see text).
** N.S.D. = No significant difference between the breed samples.
*** $.01 < p < .02$.

can be regarded as a function of its frequency in the animals being used in the production and fractionation of immune sera. The details of the calculations are too involved to justify presentation here, but it can be shown that in isoimmunizations the antigens present in the chosen donors of relatively low frequency in the remainder of the experimental population are more likely to be detected than are antigens of high frequency. Other considerations complicate this picture, but the salient fact remains that the technique itself as applied in this work to date acts largely to select antigens

in a particular frequency range. Furthermore, as was noted earlier in this paper, although the simple allelic relationship between the presence and absence of any particular antigen is well supported by genetic evidence, and although immunologically the antigens are distinct, tests for genetic independence between different antigens leave no doubt that many are genetically associated. There is evidence for the existence of complex allelic series or very closely linked factors governing the production of two or more antigens. These genetic associations will be presented elsewhere. It is sufficient here to note that although "gene frequencies" can easily be computed from the data in table 1, in many cases they may be abstractions representing the combined frequencies of a number of different alleles, and that the "gene frequency" for a given antigen may not be independent of that for another.

It remains to be seen whether or not the samples reported here are numerically adequate to charatcerize the two breeds. It is possible that a further accumulation of data may lead to some modifications of detail in the suggested picture of breed differences in blood type. In our opinion, however, further studies will probably only emphasize the main findings reported here, for example, that the genetic differences between the breeds are primarily the result of differences in gene frequency among genes common to the breeds.

Summary

Frequencies of 30 cellular antigens in a sample of 569 Guernseys were compared with those of 513 Holstein-Friesian cattle. Not all animals were tested for all antigens. Eighteen of the antigens were found to be significantly more frequent in Guernseys; seven were not significantly different in frequency in the two breeds; while five were significantly more frequent in Holsteins. There was a marked tendency for the relative position of an antigen's percentage-frequency on the scale in one breed to agree with its relative position in the other. The profile of percentage-frequencies in each breed was similar to that expected from the characteristics of the technique of detection of antigens.

No single antigen by itself distinguishes these two breeds. Rather, the breed differences in blood type are the result of quantitative differences in the frequencies of most of the antigens. Although the computation of simple gene frequencies cannot be accomplished until the genetic associations between antigens are better established, there is little doubt that the breed differences in antigen frequency are the result of contrasting gene frequencies among genes common to the two breeds. Each breed appears to be potentially capable under selection of producing individuals identical in blood type with members of the other breed.

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COMPARISON OF GROWTH OF HEREFORD AND F_1 HEREFORD×SHORTHORN HEIFERS[1]

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CROSS-BREEDING in range cattle was a common and often unavoidable practice in the open-range days, due to the mixing of stock from different owners and the use of different breeds and types of bulls. The result of this method of management is reflected in photographs showing early-day roundup and trail scenes where well-marked Hereford and Shorthorn cattle are mixed with typical Hereford×Shorthorn crossbreds. Many cattle raisers in later years, operating under fenced or closed range, followed the plan of alternating the use of Hereford and Shorthorn bulls on mixed-cow herds to produce the large three- and four-year-old steers necessary to fill existing market demands. The quality and quantity of beef produced under these methods are matters of historical importance. Subsequent trends in cattle production brought about by fenced ranges, changed market demands, pure-sire laws and agricultural education have been responsible for a gradual grading-up of range herds along definite breed lines. This change from casual methods of breeding with a miscellaneous assortment of stock to orderly, well-regulated production of high-grade Hereford, Shorthorn or Aberdeen-Angus cattle represents definite progress. However, the possibility that some of the desirable effects of hybrid vigor, due to cross-breeding, may be used advantageously through a systematic method of cross-breeding high-grade parent stock, is worthy of consideration by modern cattle producers.

Cross-breeding experiments, in which Hereford cows were bred to Shorthorn bulls and the F_1 crossbred females were mated to Aberdeen Angus bulls, were started at the U. S. Range Livestock Experiment Station, Miles City, Montana, in 1938. In order to test the possibility of heterosis through continued crossing within the three breeds of successive generations, the triple-cross females will be bred back to Hereford and succeeding generations to Shorthorn and Aberdeen Angus bulls.

The steer phase of this project, reported by Phillips *et al.* (1942) indicated that F_1 crossbred steers (Hereford×Shorthorn) when compared with Hereford steers were significantly heavier at birth and weaning and produced significantly heavier gains in the feed lot. Differences in efficiency of

[1] Based on work conducted by the United States Department of Agriculture in cooperation with the Montana Agricultural Experiment Station.

[2] U. S. Range Livestock Experiment Station, Miles City, Montana.

gains between the two breeds were not significant but the crossbred steers brought in substantially greater net returns above feed and marketing cost than the purebred steers. The crossbred steers were less subject to digestive disturbances than the Hereford steers. An analysis of the data indicated that crossbred steers were less variable than the Hereford steers.

Materials and Methods

The heifers used in this study were from the same purebred Hereford and Hereford×Shorthorn F_1 matings as the steers reported by Phillips *et al.* (1942). Both groups of heifers were out of cows of purebred ancestry randomized each year for breeding. Hereford test heifers born in 1939 were sired by two registered Hereford test bulls, while those born in 1940 were sired by three other registered Hereford test bulls. Crossbred heifers in 1939 and 1940 were sired by two full-brother Shorthorn bulls.

The management of the heifers from the two groups, with minor exceptions, was the same from birth until approximately 30 months of age. The calves were born on the range during April and May, weaned late in October and grazed on alfalfa pasture at headquarters from 30 to 45 days each year before winter feeding began. There was a difference in management, however, between the two 140-winter feeding periods as calves. During the 1939–40 feeding period the heifers were fed separately the same weight of hay per 100 pounds live weight, but the amount of hay fed or rate of feeding was governed by the amount consumed by a group of purebred heifers that lagged behind in hay consumption. During the 1940–41 winter period the three Hereford groups by different sires were fed separately, while the two crossbred sire groups were fed together, and all groups received alfalfa hay ad libitum. There was also a difference in the management of the two breeds of heifers during the 7-weeks breeding season in 1941 and 1942. Hereford heifers were allotted at random to the various test herds in 1941 and 1942, while crossbred heifers were bred in a single unit in 1941 and in two units in 1942. Crossbred heifer herds were held close to headquarters in small pastures on various types of forage and were bred to Aberdeen-Angus bulls, while the Hereford heifers were, for the most part, on native range throughout the period. All groups, however, were combined from the close of the breeding season until fall weights were secured in mid-October.

The heifers ran together on the native range, as yearlings and 2-year-olds, had access to the same kind and quality of feed, and were weighed and scored through the same periods. Differences existing between the two groups with respect to growth and final weights should therefore be considered as being due largely to breed differences.

Growth Data

The data for 55Hereford and 53 Hereford × Shorthorn heifers from birth to 30 months of age are shown in table 1. The mean differences between groups and statistical significance are shown in table 2.

TABLE 1. COMPARISON OF GROWTH BETWEEN HEREFORD AND HEREFORD×SHORTHORN HEIFERS

Breed		Hereford			Hereford×Shorthorn		
Year born		1939	1940	Mean	1939	1940	Mean
Number of sires used		2	3		2	2	
Number of heifers[1]		21	34		23	30	
Average birth weight	pounds	76.7	72.4	74.1	77.0	77.1	77.1
Average weaning weight	do	388.8	384.7	386.3	390.7	395.7	393.5
Average age weaned	days	178.1	185.3	182.5	175.9	177.5	176.8
Weaning weight corrected for age at weaning	pounds			379.9			400.1
Average gain birth to weaning	do	312.1	312.3	312.2	313.7	318.5	316.4
Gain birth to weaning corrected for age	do			305.5			323.4
Average weight—18 months	do	737.9	717.9	725.5	765.8	784.6	776.4
Average weight—30 months	do	1090.8	1024.4	1049.7	1163.4	1118.0	1137.7
Average gain weaning to 30 months	do	702.1	639.7	663.5	772.7	722.3	744.2
Average body score—yearlings	%	69.6	72.9	71.6	73.6	77.1	75.6

[1] Based on number on hand in fall at approximately 30 months of age.

TABLE 2. SUMMARY OF ANALYSIS OF VARIANCE BETWEEN HEREFORD AND HEREFORD×SHORTHORN HEIFERS (CROSSBREDS) BORN IN 1939 AND 1940—108 HEAD

Item		Mean difference between groups	Significance of differences
Birth weights	pounds	3.00	**
Weaning weights corrected for age	do	20.20	**
Gain birth to weaning corrected for age	do	17.9	**
Weights at 18 months	do	51.0	**
Weights at 30 months	do	87.9	**
Gain weaning to 30 months	do	80.7	**
Body scores as yearlings	percent	4.0	**

**, $P < .01$.

The crossbred heifers were significantly heavier at birth than the Hereford heifers, mean difference being 3.0 pounds, and exhibited less variability between years. Hereford heifer calves born in 1940 were lighter than those born in 1939.

The Hereford heifers were older and lighter at weaning time than the crossbred heifers, resulting in a corrected difference in weight amounting to 20.2 pounds. This difference is highly significant. Difference in gain from birth to weaning corrected for age between groups for the two periods amounted to 17.9 pounds. This difference is highly significant.

Weights and accumulated gains for crossbred heifers were significantly greater than weights and gains for Hereford heifers at 18 and 30 months of age, with a mean difference of 87.9 pounds in weight at 30 months of age. Heifers in both groups from the 1940 calf crop were lighter in weight at 30 months of age than those from the 1939 calf crop, indicating the presence of an environmental influence affecting both groups.

Heifers in both groups were scored by a committee at the close of each grazing season as yearlings, on the basis of beef type. The average score in percent was 75.6 for the crossbred heifers as compared with 71.6 percent for Hereford heifers or a statistically significant difference amounting to 4.0 percent.

Summary

Results presented in this paper show the growth records and weights at 30 months of age for 53 F_1 Hereford × Shorthorn crossbred heifers and 55 Hereford heifers, all out of random-selected Hereford cows. This experiment is designed to test the possibilities of maintaining heterosis through a system of criss-cross breeding with Shorthorn, Aberdeen-Angus and Hereford sires on a Hereford female foundation. Analysis of the first phase of the experimental data brings out the following points:

1. Crossbred calves were significantly heavier at birth and at weaning than Hereford calves and made significantly greater gains from birth to weaning.

2. Crossbred heifers were significantly heavier than Hereford heifers at 18 and 30 months of age.

3. Crossbred heifers had significantly higher body scores as yearlings than Hereford heifers.

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THE DESICCATION AND ANALYSIS OF FECES IN DIGESTION EXPERIMENTS WITH STEERS

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Introduction

A RECENT report on the evaluation of feeds by Mitchell (1942) furnishes convincing evidence of the need for extensive research in the field of ruminant digestion, particularly with respect to the capacity of animals under varying conditions to digest and metabolize the nutrients in complete rations and in the individual feeds that make up such rations. Further, this report and also a recent paper by Forbes, Bratzler, and French (1940) call attention to imperfections in the procedures commonly employed in determining the apparent digestibility of the nutrients in feeds. These imperfections relate to the variable composition of feeds, their associative effects when combined in rations, the levels at which they are fed, and many other factors which, unless taken into account, give false significance to the expressed digestion coefficients. Inevitable inaccuracies in technic, biological errors, and possible errors in chemical analysis of feeds and excreta contribute to the total error in any digestion trial. Some of the latter less apparent errors are considered in the present paper.

An established procedure in the proximate analysis of feces is to determine nitrogen (protein) on the fresh or preserved sample previous to drying (Forbes and Grindley, 1923) and to conduct the rest of the analysis on air-dry material. This procedure is recommended because of recognized losses during drying, although frequently in the analysis of human feces nitrogen determinations are made on samples which have been dried after the addition of acid-alcohol. The extent of the losses that occur probably vary according to the composition of the feces and to the drying temperatures employed which may range from 60° to 100°C. It was to determine the extent of these losses from the feces of steers that certain of the following experiments were initiated.

Experimental Procedure and Results

Digestion experiments were carried out at intervals over a period of nine months with steers receiving a basal ration of native grass supplemented with cottonseed cake (Hobbs, Gallup and Taylor, 1943). The details of these experiments are omitted since they are irrelevant to the discussion.

[1] Present address of C. S. Hobbs is Department of Animal Husbandry, Cornell University.

The feeds were sampled twice daily when the animals were fed and the air-dry samples were combined for chemical analysis at the end of each digestion period. The feces were collected in canvas sacks strapped to the steers with a harness. Aliquots of the feces were taken twice daily and preserved with thymol in sealed gallon jars. These aliquots were kept in an electric refrigerator until the end of the digestion period when they were remixed and samples taken for analysis.

Nitrogen Losses in Drying Feces

The original moisture content of the fresh feces was determined by drying 100-gram samples to constant weight at 105°C. The original nitrogen content of the feces was determined on triplicate 10-gram samples by the Kjeldahl method (A.O.A.C., 1940). Duplicate samples weighing 250 grams were dried to constant weight in pyrex dishes in an electric oven at temperatures of 60° and 100°C. A mixture of hydrochloric acid and alcohol in varying amounts was added to some of these samples previous to drying to stabilize the nitrogen. The dried samples were then ground and brought to an air-dry condition, care being taken to avoid exposure to the ammonia fumes of the laboratory. Nitrogen and moisture determinations were made on 2-gram portions of these air-dry samples and the nitrogen content calculated to a moisture-free basis. The effects of drying at different temperatures and the addition of various amounts of acid on the loss of nitrogen in drying these samples are shown in table 1.

TABLE 1. NITROGEN LOSSES IN DRYING FECES

Drying temperature	Samples	Average nitrogen content on dry basis	Additions before drying		Per cent of total nitrogen lost in drying		
			HCl	Alcohol	Min.	Max.	Ave.
°C	*number*	*per cent*	*ml.*	*ml.*			
100	19	1.41	0	0	4.3	10.7	6.5
100	7	1.46	1.0	9.0	1.9	8.2	5.1
100	5	1.49	1.0	24.0	1.9	4.8	3.6
100	6	1.47	2.5	22.5	1.0	5.8	3.4
100	2	1.11	5.0	20.0			0.3
60	4	1.58	0	0	4.1	6.4	4.8
60	4	1.58	2.5	22.5	2.7	5.3	4.3

When the feces were dried without the addition of acid, the loss of nitrogen varied from 4.3 to 10.7 per cent in samples dried at 100°C., and from 4.1 to 6.4 per cent in samples dried at 60°C. The addition of acid previous to

drying decreased but did not entirely prevent the loss of nitrogen. The addition of 25 ml. of 4 percent acid-alcohol was slightly more effective than the addition of 10 ml. of a 10 percent solution in preventing nitrogen losses at 100°C., probably as a result of more thorough distribution of acid throughout the sample. In the presence of an even larger quantity of acid, 25 ml. of 10 per cent acid-alcohol, the samples continued to lose nitrogen, however, at both 60° and 100°C. Two samples of feces showed no appreciable change in nitrogen content when dried at 100°C. after the addition of 25 ml. of 20 percent acid-alcohol. However, this quantity of acid interfered with subsequent determinations of fat and crude fiber besides creating conditions favorable to the absorption of ammonia from outside sources.

Absorption of Moisture by Dry Feces

The determination of moisture in feeds and particularly in hygroscopic material of high fiber content should be made by drying the samples to constant weight, or for a specified length of time, in dishes provided with tight-fitting lids (A.O.A.C., 1940). The lids protect the dry samples against atmospheric moisture during cooling and weighing. These determinations are customarily made in groups of 12 or more, and, in order that the dry residues may be used for the determination of ash, drying is carried out in platinum or porcelain dishes. Provision ordinarily is not made for covering the samples during the time they are being weighed. That the latter practice will produce a significant error in moisture determinations is shown in the following experiment.

Twelve 1-gram samples of air-dry feces in numbered porcelain crucibles without covers were dried in an electric oven at 105°C. for 5 hours. They were cooled in a desiccator containing fresh calcium chloride, and weighed in numerical order. The weighings required less than 30 minutes, and after each sample was weighed it was returned to the desiccator. After the 12th sample was weighed, the first sample was reweighed and found to have gained slightly over 100 mgms. The procedure was repeated with other 2-gram samples and with the same samples redried and reweighed in reverse order. It was found that under the prevailing conditions of relatively high humidity sufficient moisture was taken up by the samples during weighing, and as the result of opening the desiccator twelve times, to account for an error between 10 and 15 percent of the true moisture content of the 12th sample. The magnitude of the error of the other samples always varied according to the order in which the weighings were made, being negligible in the case of the first four weighings. Repetition of this work during extended periods of relatively low humidity gave evidence of errors of only 2 or 3 percent when as many as eight samples were weighed from the same desiccator.

Errors in Ether-Extract

The above error, which is attributed to the absorption of moisture by oven-dried feces under conditions of high humidity, also occurs in the determinations of ether-extract (fat) and crude fiber when these constituents are calculated by difference. In the case of ether-extract, however, a more conspicuous error is made by the substitution of ordinary quality ether for the anhydrous alcohol-free reagent specified in established procedures for the determination of fat (A.O.A.C., 1940). That such a substitution is sometimes made in feed analysis is indicated by the high results reported for the crude fat content of many forages. The extent of the error in analysis of feces was found by comparing the results obtained when these two types of ether were used for extraction.

Two-gram samples of feces in glass extraction thimbles with cotton plugs were oven-dried and extracted with anhydrous di-ethyl ether for 16 hours. Duplicates of these samples were dried at the same time and extracted with di-ethyl ether designated as "purified" for fat extraction. After extraction, the samples were redried and weighed and the loss of weight calculated as ether-extract. The use of purified ether produced an average error of 25.9 percent in the crude fat content of 6 samples and 20.3 percent in that of 4 samples. Subsequent determinations showed that the magnitude of the error varied with different lots of ether.

Proximate Analysis Conducted on Wet Feces

It is a generally accepted fact that thorough mixing of wet feces, with precautions against loss of moisture, will permit accurate sampling of the material for protein determinations; for feces of relatively low moisture content, random sampling and remixing of the smaller samples is recommended (Forbes and Grindley, 1923). The reliability of this procedure was confirmed in the present experiments, by the small variation found in the nitrogen content of triplicate 10-gram samples. The difference between triplicates was usually less than 0.5 mg. in samples containing between 30 and 40 mgms. of nitrogen. These results suggested the possibility of making a complete analysis on 10-gram samples of wet feces and thereby avoid preliminary drying, grinding, and remixing of large aliquots.

For this purpose, quadruplicate 10-gram samples of well-mixed aliquots of fresh feces were weighed into tared crucibles and dried to constant weight for the determination of moisture. One pair of these was used for the determination of ash and the other was ground in a mortar and transferred quantitatively to glass extraction thimbles for the determination of ether-extract. Tared thimbles should be used in case this transfer is not quantitative. The residues from the ether extraction were used for the determination

of crude fiber. The results of these analyses were compared with those obtained in the usual manner on ground air-dry samples prepared from 250 grams of the fresh feces. A total of eight comparisons was made with steers receiving dry grass, and twelve comparisons with steers receiving silage and grain rations. Representative results which include all rations are given in table 2.

TABLE 2. COMPOSITION OF FECES AS DETERMINED BY ANALYSIS OF FRESH AND AIR DRY SAMPLES

Ration number[1]	Steer number	Condition of feces	Weight of feces	Dry matter of feces	Composition of dry matter in feces				
					Ash	Protein	Ether-extract	Crude fiber	Nitrogen-free extract[2]
			gm.	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*
1	1	fresh	10	17.91	18.81	8.44	3.07	22.45	47.23
		air-dry	2	93.27	18.81		3.32	21.98	47.45
2	8	fresh	10	17.37	12.00	11.40	2.41	22.24	51.95
		air-dry	2	95.22	11.87		2.44	21.82	52.47
3	12	fresh	10	15.79	12.66	9.63	2.20	21.80	53.71
		air-dry	2	95.14	12.65		2.50	21.34	53.88
4	11	fresh	10	16.08	10.64	7.71	1.95	25.56	54.14
		air-dry	2	95.40	11.15		2.12	24.37	54.65
5	10	fresh	10	18.19	10.95	13.99	2.77	20.35	51.94
		air-dry	2	95.60	11.15		2.89	20.32	51.72
6	7	fresh	10	18.43	11.91	13.62	3.17	21.35	49.95
		air-dry	2	95.53	11.75		3.19	21.63	49.81
7	9	fresh	10	19.25	11.28	13.57	2.57	21.09	51.49
		air-dry	2	95.69	11.23		2.66	20.87	51.67

[1] Ration No. 1 was dry grass. The other rations were composed of sorghum silage with the following supplements: No. 2, cottonseed cake; No. 3, soybean meal; No. 4, oats; No. 5, soybean meal and barley; No. 6, oats and barley; No. 7, cottonseed cake and barley.

[2] The results of protein determinations made on fresh feces were used in calculating nitrogen-free extract by difference.

A study of the complete results disclosed no uniform variation in the percentage composition of fresh and air-dry feces which might be ascribed to the procedure employed in analysis. In practically all instances the variation between results obtained on fresh and air-dry samples were no greater than those between duplicates of the latter. The greatest variation in ash content occurred in the feces from steer 11 on ration 4 although this difference of 0.51 percent was slightly less than 5 percent of the amount found in the air-dry sample. The same is true of the variation in the crude fiber content of these samples. Protein determinations were made only on fresh samples to avoid known errors. Difference between the fresh and air-dry samples in ether-extract were considerable when this difference is expressed as a per-

centage of the small amounts present in the latter samples, the greatest difference being found in the feces from steer 12 on ration 3. The results of nitrogen-free extract calculated by difference showed good agreement.

Discussion

Fresh feces lost from 4 to 11 percent of its total nitrogen content during drying at 60° and 100°C. Because this error is made on the undigested portion of the feed, its effect on the protein digestion coefficient will decrease as the digestibility of the protein increases. A 10 percent loss of nitrogen due to this error will increase the digestion coefficient of protein that is 50 percent digestible by 5 percentage units, and one that is 80 percent digestible by 2 percentage units. Since the loss of nitrogen was not entirely prevented by the addition of acid before drying, it seems appropriate again to emphasize the importance of conducting this determination on well-preserved fresh samples (Cochrane, Fries and Braman, 1925) (French, 1930).

The error produced by atmospheric moisture in weighing oven-dried samples of feces in open dishes assumes considerable importance where the loss of weight of dried samples following extraction with ether is calculated as ether-extract. In the case of feces containing 4 percent of ether-extract, a weighing error of 1 percent resulting from the absorption of moisture will produce an error of 25 percent in the ether-extract determination. An error of similar magnitude in this determination resulted from the extraction of feces with impure ether. A 25 percent error made in either manner on feces will account for a marked change in the apparent digestion coefficient of crude fat in ruminant rations of naturally low fat content and may easily change low positive values to negative ones.

The ash content of feces can be determined with a high degree of accuracy by careful control of furnace temperatures between 600° and 650°C. Crude fiber determinations are subject to considerable error. The effectiveness of these errors can be largely eliminated by conducting this determination on feeds and corresponding samples of feces at the same time under comparable conditions. Extreme fineness of grinding of samples which results in low values for crude fiber should be avoided.

The success with which proximate analysis can be made on small samples of fresh feces will probably depend upon the nature of the rations fed and the consistency of the feces which determine sampling error.

Summary

The problem of inaccuracies in apparent digestibility coefficients was approached from the standpoint of simple errors associated with the usual analysis of feeds and feces in digestion trials.

Errors of 10 percent in moisture, from 4 to 11 percent in nitrogen, and from 20 to 25 percent in ether-extract were readily demonstrated in the determination of these constitutents in feces by unreliable procedures.

The errors of fecal analysis were shown to effect large errors in digestion coefficients of constituents that are poorly digested and small errors in the coefficients of those that are quite completely digested. Precautions were recommended to prevent these errors.

A procedure was suggested for the analysis of fresh feces which gave results in good agreement with those obtained on ground air-dry samples. This procedure, which may prove to have practical value, merits further study under other experimental conditions.

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SEASONAL VARIATION IN CHEMICAL COMPOSITION OF PASTURE HERBAGE AND THE RELATION TO ITS DIGESTIBILITY BY STEERS AND SHEEP. (PASTURE STUDIES—XXVI)

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THE digestibility of the dry matter of pasture herbage under eastern Canadian conditions may vary from 80 percent in the early spring to 60 percent or less during mid-summer. The factors which cause these changes in digestibility are not fully known, but there is reason to believe that changes in digestibility reflect changes in nutritive value of feed. It is unlikely that either amount or quality of protein limit the feeding value of pasturage to grazing ruminants. The protein content of such material normally does not fall below 15 percent and ruminant digestion appears to be wholly independent of amino acids in the diet. It is presumed that synthesis of necessary amino acids may occur in the rumen from a variety of sources of dietary nitrogen.

Available energy, on the other hand, is correlated with the feeding value of any ration. Since ration energy losses through incomplete digestion of the potential energy yielding fractions are variable between different diets, it is assumed that seasonal trends in the digestibility of the energy-yielding portions of pasture herbage indicate seasonal changes in the nutritive value of such feed.

Critical examination of data from this station reveals that, excepting for protein which shows little change in magnitude and none which follows season, the seasonal trends in the digestibility of the several fractions of the mixed pasturage involved in this study follow closely the trend of digestibility of the total dry matter eaten. Therefore, the discussion following will involve the digestibility of total dry matter only unless otherwise noted. It may be of interest, however, to state the order of the digestibility of certain of the feed fractions as determined from the past two years' work on this problem. The range covers the pasture season.

	Range	*Average*
Crude Protein	72–79%	76%
Ether Extract	15–61	41
Crude Fibre	57–82	69
Nitrogen-Free Extract	68–78	75
Cellulose	41–84	74
Soluble Carbohydrate	75–85	80
"Lignin" (Dif.)	2–58	34
Total Dry Matter	68–80	71

[1] Contribution from Faculty of Agriculture, McGill University, Macdonald College, Quebec, Canada. Journal Series No. 189.

If seasonal change in digestibility can be taken as an index of change in feeding value of pasture herbage, then this figure should be useful as a basis for studying the accuracy of schemes of chemical description intended to depict or predict feeding value of such material.

For the past three seasons, the herbage from an experimental pasture has been fed either to steers or sheep. In the case of steers, the material was cut and fed at once to animals confined to digestion stalls on the area. During the past season artificially dried clippings, taken every three weeks, were fed to sheep in digestion stalls. During the 1941 season but three digestion periods were actually carried out. In 1942 our records give a daily digestion coefficient throughout the full season. In this paper, the latter data have been grouped into seven three-week periods.

The season trends in the digestibility of the dry matter for the three seasons are shown in figure 1. It is not to be expected that these curves would coincide, but it is noteworthy that their trends are similar from early spring to mid-summer. During this period the decline in digestibility is marked,

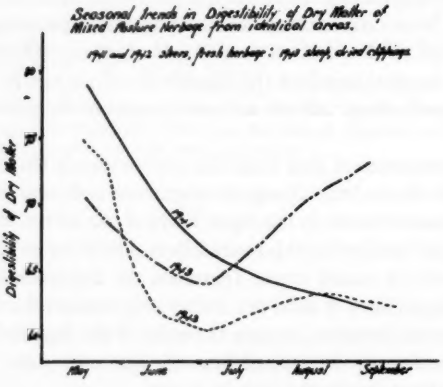

Figure 1. Seasonal trends in digestibility of dry matter.

and coincides with the maturing of the plants. There may also be changes in botanical composition during this time. (See table 3.)

After about July 1, the digestibility may either continue to fall, or rise to spring levels, depending on climatic conditions. The season of 1941 was exceedingly dry, while 1943 was the wettest season recorded for about 50 years with no dry hot period during the summer.

Rate of gain of grazing cattle also followed roughly these trends in digestibility of the dry matter of the forage.

Presumably these seasonal changes in the digestibility of pasture herbage are the result of changes in chemical composition. It is interesting to note the extent to which such changes in chemical make-up were correlated with the trend in digestibility. Data are available for the 1942 season and 1943 season only.

Table 1 gives the data for 1942. (The figures for daily feces output are of no particular interest at present.)

TABLE 1. SEASONAL TRENDS IN COMPOSITION OF MIXED PASTURE HERBAGE TOGETHER WITH DATA FOR 1) DIGESTIBILITY OF DRY MATTER, 2) AVERAGE DAILY FECES DRY MATTER OUTPUT (1942 SEASON—STEERS)

	May 28	June 7	June 17	June 27	July 17	Aug. 26	Sept. 25	Correlation of fractions with digestibility of dry matter
Dig. of dry matter (%)	76	75	72	65	70	70	68	
Av. daily feces on 17.5 lbs. D.M. intake (lbs.)	3.6	4.3	4.7	5.7	6.1	5.2	5.3	
Composition of herbage								
Crude protein (%)	16.2	18.3	14.1	21.1	17.9	18.3	19.7	−0.696
Crude fibre (%)	24.6	23.7	27.6	21.1	20.0	18.9	17.0	0.591
N-Free extract (%)	45.7	44.8	46.7	45.6	48.2	50.5	49.2	−0.425
Insoluble residue (%)	34.4	34.5	36.7	30.8	29.9	30.4	29.1	0.737
Lignin* (%)	9.2	9.6	10.5	10.6	11.6	11.1	9.9	−0.616
Lignin** (%)	7.4	5.6	12.6	4.2	6.2	9.4	9.3	0.231
Soluble carbohydrate	41.6	41.1	42.9	42.3	43.4	42.8	41.1	−0.082

* Method of Crampton and Maynard, 1938.
** Method of Crampton and Whiting, 1942.

One of the first things to be noted in these data is the *negative* and high correlation between crude protein and digestibility of the herbage. This is strong evidence towards refuting the claim that treatment to pastures resulting in increased protein correspondingly increases the nutritive value of such pastures when their lowest level of protein was much above the needs of the steers or sheep.

This is true also of crude fibre and insoluble residue.[2] These correlations are positive but would be negative if increases in crude fibre or in cellulose +lignin decreased nutritive value. The explanation obviously lies in the high digestibility of cellulose by ruminants.

[2] Insoluble residue, for practical purposes, may be taken as comparable to crude fibre obtained by omitting the dilute alkali treatment. It differs from crude fibre, therefore, in that it contains the lignin as well as the cellulose. (See JOURNAL OF ANIMAL SCIENCE, V. 2, No. 4, p. 278, 1942.)

Lignin, which it was believed might prove a useful index, is still an uncertain factor. Our studies have shown that "formaldehyde lignin" is probably too high. Lignin by the method proposed by Crampton and Whiting (1942) (*i.e.* by difference) gives values more nearly in line with the 72 percent sulphuric acid method. In the 1942 results "formaldehyde lignin" was negatively correlated, while "lignin by difference" was only slightly but positively correlated with digestibility of the dry matter.

The 1943 data involving artificially dried clippings fed to sheep are shown in table 2.

TABLE 2. SEASONAL TRENDS IN COMPOSITION OF MIXED PASTURE HERBAGE TOGETHER WITH DATA FOR 1) DIGESTIBILITY OF DRY MATTER, 2) AVERAGE DAILY FECES DRY MATTER OUTPUT (1943 SEASON—SHEEP)

	June 1	June 21	July 14	Aug. 4	Aug. 25	Sept. 15	Correlation of fractions with digestibility of dry matter
Dig. of dry matter (%)	75	69	69	72	73	75	
Av. daily feces on 1176 gms. D.M. intake (gms.)	289	367	363	332	319	290	
Composition of herbage							
Crude protein (%)	17.9	17.3	21.3	25.5	25.8	26.3	0.337
Crude fibre (%)	20.9	17.3	19.7	17.9	17.9	15.4	−0.063
N-Free extract (%)	48.2	48.1	45.3	43.3	43.8	46.2	0.075
Insoluble residue (%)	29.8	32.8	31.8	32.0	30.3	25.7	−0.080
Lignin* (%)	10.4	11.4	17.2	20.2	20.0	16.9	−0.003
Lignin** (%)	5.6	6.6	8.9	7.5	8.1	5.4	−0.663
Soluble carbohydrate	42.7	42.0	38.2	37.3	36.8	41.8	0.310

* Method of Crampton and Maynard, 1938.
** Method of Crampton and Whiting, 1942.

Here crude fiber shows no appreciable correlation in trend with digestibility of dry matter; nor does insoluble residue or "formaledehyde lignin." Protein is slightly correlated. The "lignin by difference" shows a high and negative correlation; but the change in lignin values during the season is small.

In connection with these data, the change in botanical make-up of the herbage is interesting. (Readings represent ground cover.)

Evidently change in clover content did not correlate with change in digestibility. Indeed the highest digestibility was found in the periods when the clover content was least. The influx of clover, however, undoubtedly was a factor in the climb in percent protein in the mixed herbage from spring to fall.

The trends in the composition of the herbage for the two seasons 1942 and 1943 are shown graphically in figures 2–5. There is no rhyme nor reason to the crude fibre trends: the protein trends are influenced by change in botanical composition; nitrogen-free extract is naturally complementary to protein as is soluble carbohydrate. Insoluble residue, which is really crude fibre not treated with alkali, drops from spring to fall but fails to be low in the spring as it would be if it were to serve as an index of digestibility. The combined soluble carbohydrate and soluble protein, which might be taken

TABLE 3. DIGESTIBILITY OF ARTIFICIALLY DRIED CLIPPINGS OF MIXED PASTURAGE BY SHEEP
(1943 SEASON)

Date clipped	Digestibility of dry matter	Notes re herbage as clipped
June 1	75.4%	Herbage about 10 inches in height. Botanical make-up was: Grasses 65%— Timothy 42% Ky. Blue 2 Couch Grass 12 Clovers 30%— Wild White 14 Alsike 13 Red 3 Weeds 14%— Daisy, Dandelion.
June 21	68.8%	Herbage 6–8 inches tall. Clovers now 50% of ground cover.
July 14	69.1%	Herbage 5 inches tall. Clovers about 55% of ground cover. Weeds are few; grasses chiefly timothy and red top.
Aug. 4	71.8%	Clovers now make up 65% of ground cover; grasses 30% and weeds 5%.
Aug. 25	72.9%	No readings.
Sept. 15	75.3%	Clovers reduced to 42%, mostly wild white; grasses 55% with 90% of it timothy; weeds 3%.

in non-herbivors as an index of total energy value, does not follow the same trend in the two seasons. "Lignin" as estimated by either of two methods can not be relied on to indicate the trends in digestibility of dry matter in this type of feedstuff.

General Observations and Conclusions

Under eastern Canadian conditions, mixed pasturage consisting principally of timothy, red top, blue grass, with or without wild white clover, is the most important single feedstuff for dairy cattle. Through long neglect, many pastures are badly run down and the nutritive value of the herbage is obviously low. Fertilizer treatments restore such areas to increased carry-

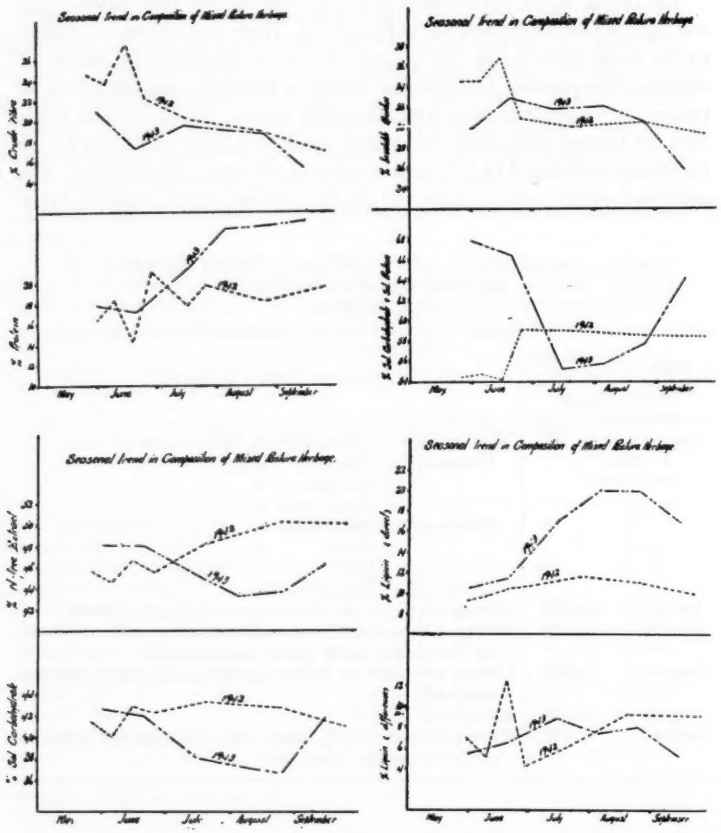

Figure 2 (upper left). Seasonal trends in crude fibre and protein content of mixed pasture herbage.

Figure 3 (upper right). Seasonal trends in insoluble residue and soluble carbohydrates plus soluble protein.

Figure 4 (lower left). Seasonal trends in nitrogen-free extract and soluble carbohydrate.

Figure 5 (lower right). Seasonal trends in lignin.

ing capacity, some of which is traceable to an improvement in the nutritive value of the herbage and some to increase in yield of forage.

Improvement in nutritive value has been claimed for different treatments in many pasture studies on the basis of a resulting increase in protein and/or

decrease in fibre content of the herbage. In the light of the data above presented, such conclusions are unwarranted. Neither of these proximate principles differ significantly in their digestibility from each other or from that of the total dry matter. Furthermore, changes in either fraction during the season are either not correlated at all, or are correlated contrary to expectation with the concomitant changes in the digestibility of the dry matter eaten.

Protein and fibre fail as indices of nutritive value as do all other fractions reported in this paper.

There appears to be a characteristic steady decline in the digestibility of pasture herbage dry matter from values of the order of 75 percent for early spring grass to 60 percent some six weeks later. Digestibility from this time on may rise again, further decline, or remain at the mid-summer level, apparently not depending on chemical changes indicated by standard feedingstuffs analysis or its modifications herein described, but closely paralleling local climatic conditions of moisture and temperature.

The authors believe it is much easier to predict, from observation of seasonal conditions, the probable chemical make-up of the herbage than its digestibility.

The digestibility of mixed pasture herbage by steers and by sheep appears to follow quite closely the leaf/stem ratio existing at the time. A wide ratio means high digestibility which decreases as the material increases in proportion of stems. This is not a new idea, but it is one which may hold the secret of measurement of the nutritive value of such a highly variable feed as pasture. Changes in the toughness of the stems noticeable in clipping, but too small to be evident on casual observation, are promptly reflected in increased feces output on constant levels of feed intake. It seems reasonable that these changes are accompanied by or the result of some change in chemical composition which could be easily measured.

It is possible that changes in the activity and nature of rumen flora of microorganisms are occasioned by chemical and/or physical changes in the herbage which in turn are reflected in "digestibility" of the ration.

These may include or consist of factors not now measured in the usual feedingstuffs analysis. Certainly it is known that treatments of cellulosic materials with numerous chemicals, particularly alkali, to partly do what bacteria seem to do in the rumen, results in an increase in their digestibility and nutritive value.

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PLASMA ASCORBIC-ACID VALUES OF SHEEP OF VARIOUS AGES FED DIFFERENT RATIONS[1]

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THE relationship of plasma ascorbic acid levels to breeding performance has been elucidated by Phillips and associates (1940, 1941) for cattle and by Davis and Cole (1943) for horses. More recently Cole and associates (1944) encountered an ecezematoid disease of dairy calves that is associated with low plasma ascorbic-acid values.

Information on the ascorbic acid content of sheep's plasma is meager, and as a relatively large number of sheep of various ages were available work was undertaken to study this factor. This paper records blood plasma ascorbic acid values of feeder lambs on different rations, ewes before and after lambing on different rations, and suckling lambs.

Experimental

The feeder lambs used in this study were selected from six lots of 20 lambs each (15 Southdown × western finewool and 5 Corriedale × western finewool) which were being fed in a study of "overeating" disease (enterotoxemia). The individual lambs weighed 44 to 69 pounds at the beginning of the feeding period.

Five lambs from each lot (four Southdown crossbreds and one Corriedale crossbred) were selected for determination of plasma ascorbic acid values. The lambs (except lot 3) were fed 163 days on the rations listed in table 1 and plasma ascorbic acid determinations were made on the 28th, 40th, 62nd and 146th days. The lambs of lot 3 were on experiment 123 days and were bled on the 28th, 40th and 62nd days.

The ewes were being fed for a study of "stiff-lamb" disease and were from the college flock of Hampshires, Shropshires, Rambouillets and Black Top Delaines. The youngest ewe was two years old. Three lots of 8, 15, and 8 ewes respectively were available.

The ewes were placed on the rations about half way through the gestation period, but grain feeding was not begun until about one and one-half months prior to parturition. The rations fed the ewes are listed in table 1.

[1] Published with permission of the Director of the Experiment Station as journal article (n.s.). 705. The authors wish to express their appreciation to Anheuaer-Busch and Co., Inc., St. Louis, Missouri, for furnishing the dried yeast used in these studies.

[2] Section of Chemistry.

[3] Section of Animal Husbandry.

[4] Section of Animal Pathology.

Blood samples were drawn from all animals at a 35-day interval. The first samples were taken from 1 to 30 days before lambing and the last samples from 1 to 30 days after lambing.

Forty suckling lambs (22–47 days old) from the college flock were bled for this study. The group was made up of ten each of Rambouillets and Shropshires, and five each of Southdowns, Cotswolds, Hampshires and Oxfords. The dams of these lambs were getting a ration of the same kind of hay fed

TABLE 1. RATIONS FED TO THE FEEDER LAMBS AND EWES

Ingredients*	Feeder lambs						Ewes		
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 1	Lot 2	Lot 3
Alfalfa hay**	0.5	0.5	0.5	ad. lib.	ad. lib.	0.5	ad. lib.	ad. lib.	—
Corn silage	—	—	—	—	—	—	—	3.0	3.0
Oat straw	—	—	—	—	—	—	—	—	ad. lib.
Bean pods	—	—	—	—	—	ad. lib.	—	—	—
Oats	—	—	—	—	—	—	—	1.0	—
Corn	ad. lib.	ad. lib.	ad. lib.	ad. lib.	ad. lib.	ad. lib.	—	—	1.0
Soybean oil meal	—	0.2	—	—	0.2	—	—	—	—
Soybean oil meal +Yeast (1+1)	—	—	0.2	—	—	—	—	—	—
Sugar beet molasses	0.1	—	—	—	—	—	—	—	—

* Pounds per head daily unless otherwise stated.

** The hay was the same fair quality for all animals except lot 1 of the ewes. The hay for this group was of good bright quality.

the ewes in lot 2 and a pound per head daily of a grain mixture of oats and soybean oil meal.

All blood samples were drawn, placed in a cold, dark container and immediately taken to the laboratory for analysis of plasma ascorbic acid by the method of Mindlin and Butler (1937).

Results and Discussion

The feeder lambs (lots 1 through 6) gained respectively 0.19, 0.23, 0.20, 0.21, 0.27 and 0.17 pounds per head daily over the experimental period. All but seven of these animals sold at a premium on the Detroit market.

The ewes were all in good health during the feeding period. However the ewes of lot 3 were somewhat thin after lambing.

The suckling lambs at the time of bleeding were all in excellent condition and growth rates of these lambs were excellent.

The mean and standard deviation, and the variation in results are recorded in table 2.

The feeder lambs of lots 3, 4 and 5 had higher plasma ascorbic-acid values than those of lots 1, 2 and 6. The mean and standard deviation for the plasma ascorbic-acid values for lots 1, 2 and 6 collectively is 0.44 ± 0.14 mg. per 100 ml. These lambs were fed a limited hay ration with corn and with or without soybean oilmeal and molasses. The plasma ascorbic-acid level for the unlimited hay animals (lots 4+5) is 0.56 ± 0.16 mg. per 100 ml. Thus on high corn intakes, if the hay of the ration is limited, the plasma ascorbic-acid is lower

TABLE 2. PLASMA ASCORBIC ACID (MG. PER 100 ML.) OF FEEDER LAMBS, EWES, AND SUCKLING LAMBS

Group	Lot	Variation (range)	Mean ± standard deviation
Feeder lambs	1	0.26–0.65	0.44±0.13
	2	0.24–0.66	0.43±0.14
	3	0.24–0.95	0.54±0.16
	4	0.25–1.02	0.56±0.18
	5	0.24–0.81	0.57±0.14
	6	0.17–0.67	0.46±0.14
	Average	0.17–1.02	0.49±0.16
Ewes	1	0.26–0.84	0.61±0.18
	2	0.09–1.03	0.36±0.18
	3	0.08–0.49	0.27±0.11
	Average	0.08–1.03	0.40±0.21
	Ave. before lambing	0.08–1.03	0.43±0.24
	Ave. after lambing	0.09–0.84	0.38±0.17
Suckling lambs		0.12–0.93	0.48±0.21

even though soybean oilmeal or sugar beet molasses are fed as supplements. Yeast as a supplement tends to keep the ascorbic-acid content of the plasma at the higher level of the unlimited hay groups.

The significance of these findings is not apparent at this time. No deaths from "overeating" disease were encountered in these lambs, but in a study made the previous year in which a corn field was "lambed-down" and the hay limited to one-fourth pound per head daily, a number of deaths occurred. Less than half of the deaths were due to clear cut "overeating" disease, as most deaths occurred from acites. Considering the role of ascorbic acid in maintaining the blood capillaries (Dalldorf, 1939) it is possible that lowered blood ascorbic-acid levels may be responsible for increased permeability and the resulting acites. Newsom and Thorp (1938) and Harsfield and associates

(1942) found toxins in the intestinal tract of sheep that died from "overeating" disease and these toxins will kill normal sheep when given intravenously, but are harmless when administered by mouth or injected into the small intestine. These workers believe it possible that an altered state of the intestinal mucosa is necessary before absorption of the toxin can occur. "Overeating" disease and the acites encountered by us might be manifestations of the same deficiency in which increased permeability results. In this connection it is interesting that in our previous trial no acites or "overeating" disease occurred in a lot of sheep that were drenched twice a week with a suspension of dried yeast.

The differences in ascorbic-acid plasma levels are more pronounced in the ewes (table 2). Lot 1 had very definitely higher mean plasma ascorbic-acid values (0.61 ± 0.18) than lots 2 and 3 (0.36 ± 0.18 and 0.27 ± 0.11). Lot 1 received a higher quality alfalfa hay than lots 2 and 3. Also lots 2 and 3 were restricted in their intakes of other roughage by the feeding of corn silage. Lot 3 received oat straw instead of alfalfa hay. Thus the differences in plasma ascorbic-acid levels must be due to the rations fed.

There was a slight but doubtfully significant drop in the mean plasma ascorbic acid level after lambing (0.43 to 0.38 mg. per 100 ml.).

The differences in the plasma ascorbic-acid values cannot be attributed to ascorbic acid in the ration, especially in light of the work of Vavich and associates (1944). It seems more likely that some ascorbic-acid precursors or ascorbic-acid stimulating factors are present in variable amounts in the feeds. The bright quality alfalfa hay seems to be the most potent source fed in these studies. This ascorbic-acid stimulating factor would agree with the findings of Musulin and associates (1939) that the non-saponifiable ether extract of alfalfa meal stimulates urinary excretion of ascorbic acid by the rat. Bortree and associates (1943) have shown that feeding chlorobutanol will stimulate ascorbic acid in plasma of dairy cows.

Satterfield and associates (1942) report the average ascorbic-acid content of the plasma of ewes, 20–25 days before lambing, as 0.66 mg. per 100 ml. with variations from 0.31 to 1.18 mg. per 100 ml. This value is in good agreement with that for the ewes fed bright quality alfalfa hay (0.61 mg. per 100 ml.). The ewes used by Satterfield *et al.* (1942) were fed a varied ration.

The suckling lambs had plasma ascorbic-acid values ranging from 0.12 to 0.93 mg. per 100 ml. The mean and standard deviation for the 40 lambs was 0.48 ± 0.21 mg. per 100 ml. No relationship was evident between sex or age of the lambs and plasma ascorbic-acid values. Whether the differences represent normal variations or different nutritional states will require further study. It is of interest that the plasma ascorbic-acid values for each pair of five pairs of twins were within very narrow limits.

The over-all values for the different age groups do not differ greatly from those secured by Bortree and associates (1942) for dairy cattle. These workers report mean values of 0.32, 0.49 and 0.44 mg. ascorbic acid per 100 ml. of plasma for calves, heifers and cows respectively. The mean values obtained for the sheep were 0.48, 0.49, and 0.40 mg. per 100 ml. of plasma for suckling lambs, feeder lambs and ewes respectively. The variation between suckling lambs and calves is the greatest difference, but it is possible that the suckling sheep are not comparable to the calves which were from birth to 12 months of age.

Summary and Conclusions

Determinations of plasma ascorbic-acid values were made on six lots of feeder lambs fed high corn rations. Alfalfa hay was given in limited and unlimited quantities and lots were included that were supplemented with soybean oilmeal, soybean oilmeal and dried yeast, and sugar beet molasses. The unlimited hay lots (4 and 5) had a mean plasma ascorbic-acid value of 0.56 ± 0.16 mg. per 100 ml., while the corresponding value for the limited hay lots (1, 2 and 6) was 0.44 ± 0.14 mg. per 100 ml. Molasses and soybean oilmeal had no apparent influence, but the yeast supplemented group (lot 3) had a mean plasma ascorbic-acid value of 0.54 mg. per 100 ml.

One of three lots of ewes was fed hay, a second lot received hay, silage and oats, and a third received oat straw, silage and corn. The mean plasma ascorbic-acid values were 0.61 ± 0.18, 0.36 ± 0.18 and 0.27 ± 0.11 respectively for the three lots.

Thus some ascorbic-acid precursor or ascorbic-acid stimulating factor must be present in varying amounts in the feeds used. Alfalfa hay and yeast were the two most potent sources fed.

It is possible that lowered plasma ascorbic-acid values are concerned in "overeating" disease and a type of acites that develops on corn rations.

The mean plasma ascorbic-acid value for suckling lambs was 0.48 ± 0.21 mg. per 100 ml.

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CAROTENE, VITAMIN A, AND ASCORBIC ACID IN MARE'S PLASMA[1]

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PREVIOUS work at this station (Davis and Cole, 1943) indicated a direct relationship between breeding performance and plasma ascorbic-acid values in mares.

Boyer *et al.* (1942) found the level of plasma ascorbic acid in the dairy calf to be contingent upon the level of plasma vitamin A, particularly when the vitamin A values were low.

The normal values for equine plasma ascorbic acid reported in the literature (Davis and Cole, 1943; Errington *et al.*, 1942; Pearson *et al.*, 1943; Hart *et al.*, 1943) are not in agreement. The present study was undertaken to check the ascorbic acid content of equine plasma and study its possible relationships to plasma vitamin A and carotene.

Experimental

The animals used for these studies were purebred work mares from the college herd. They were fed a barn ration of hay, grain, and salt, and with the exception of Animals Numbers 3, 6, 19 and 20, were allowed to run on pasture during the experimental period. The study of Nos. 3 and 6 was begun February 17, 1943 and the animals were kept on the barn ration until May 20, 1943 when they were given access to pasture for part of each day.

The blood samples were drawn and placed in a dark box cooled by dry ice, and then taken immediately to the laboratory for analysis. The plasma ascorbic acid was determined by the method of Mindlin and Butler (1937), and the carotene and vitamin A content was determined with the Cenco photelometer by an adaptation of Kimble's Method (1939) using carotene (90 percent beta and 10 percent alpha) and pure vitamin A alcohol as standards.

Results and Discussion

The plasma values secured for carotene, vitamin A, and ascorbic acid, are listed in table 1. The pasture began to show some growth before April 22, 1943 and a rise in plasma carotene was evident at that time. The pasture did not grow rapidly enough to contribute much feed until about May 4, 1943. The trend for carotene and ascorbic acid to increase from the prepasture to

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TABLE 1. CAROTENE, VITAMIN A AND ASCORBIC-ACID CONTENT OF MARE'S PLASMA

Date	Animal number																							
	2			3			4			5			6			7			9			10		
	C.[1]	V.A.[2]	A.A.[3]	C.	V.A.	A.A.	C.	V.A.	A.A.	C.	V.A.	A.A.	C.	V.A.	A.A.	C.	V.A.	A.A.	C.	V.A.	A.A.	C.	V.A.	A.A.
2-17-43	8.6	8.0	0.38	8.5	12.0	0.57	10.1	14.2	0.49	9.4	15.9	0.27	15.6	16.9	0.66									
2-25	12.4	8.6	0.56	7.9	11.9	0.57	11.4	15.3	0.71	14.8	15.7	0.43	23.7	15.7	0.75									
3-26	10.9	13.5	0.46	10.0	13.2	0.46	16.2	17.0	0.59	16.8	17.1	0.33	27.0	17.7	0.69									
4-22	14.5	14.4	0.40	13.8	13.6	0.47	32.5	16.0	0.44	46.7	19.3	0.28	58.8	18.2	0.56									
5-4	13.8	12.9	0.41	12.7	10.9	0.48	83.4	10.9	0.63	77.6	17.5	0.46	65.4	14.9	0.56	70.2	9.9	0.44	65.0	6.8	0.21	72.8	7.0	0.28
5-18	22.0	11.6	0.39	21.0	11.1	0.44	223.1	19.3	1.01	238.4	20.5	0.43	76.7	11.4	0.49	151.5	13.2	1.00	144.6	8.6	0.79	137.6	7.3	0.50
6-4				89.7	11.7	—	237.2	18.3	0.71	269.9	20.7	0.44	278.0	16.3	—	257.5	13.6	0.69	255.2	15.0	0.61	225.2	11.7	0.40
7-1				256.6	8.0	0.50	244.6	9.1	0.81	193.0	11.7	0.46	130.7	6.4	0.75	188.6	11.0	0.76	171.9	8.8	0.65	120.9	8.9	0.49
7-27										167.0	13.1	0.44												
8-24										92.5	10.3	0.37												
9-1										112.2	10.2	0.32												

Date	11			13			14			15			16			18			19			20		
5-4-43	76.6	12.3	0.21	37.0	11.2	0.51	25.4	10.0	0.42	24.4	6.2	0.60	35.9	13.2	0.24									
5-18	78.3	11.2	0.56	97.2	11.1	0.71	73.1	9.3	0.67	103.1	8.5	0.74	81.1	15.3	0.61									
6-4	88.1	11.6	0.62	113.3	15.9	0.57	70.4	14.5	0.51	179.6	12.1	0.52	143.4	13.9	0.52									
7-1	109.3	9.3	0.52	34.3	10.8	0.58	73.7	9.1	0.57	145.5	8.2	0.56	152.5	14.4	0.49	90.0	14.5	0.66	69.1	10.9	0.49	127.4	9.3	0.60
7-27																25.5	14.2	0.42	24.3	8.1	0.26	—	—	—
8-24																21.4	11.7	0.46	22.9	7.2	0.28	41.3	6.7	0.25
9-1																26.1	15.2	0.58	23.1	5.8	0.19	46.5	5.3	0.27

[1] (C.) Carotene, micrograms percent.
[2] (V.A.) Vitamin A, micrograms percent.
[3] (A.A.) Ascorbic Acid, mg. percent.

the pasture periods is evident in table 1. No trend between either carotene and vitamin A or between vitamin A and ascorbic acid is evident.

The data presented in table 1 were assembled according to the pasture observations and the mean and standard deviation of the mean calculated for the entire period of study, including the prepasture period ending May 4, 1943, and the pasture period beginning May 18, 1943, and continuing to September 1, 1943. However, the pasture was starting to decline during the last two weeks. These findings are tabulated in table 2.

TABLE 2. MEAN AND STANDARD DEVIATION OF THE MEAN, FOR THE ENTIRE, PREPASTURE, AND PASTURE PERIODS

Period	Carotene, microgram %	Vitamin A, microgram %	Ascorbic acid, mg. %
Entire	97.0±78.0	12.5±3.5	0.53±0.17
Prepasture	34.6±24.6	12.8±3.6	0.42±0.17
Pasture	134.9±71.0	12.5±3.4	0.59±0.16

Animals Nos. 3 & 6 were not considered in table 2 because they were kept in the barn, and No. 6 was definitely a difficult breeder. Numbers 19 and 20 were not considered because they were difficult breeders and were kept in the barn to July 1, 1943. Number 20 was fed ascorbic acid for the two weeks prior to July 1, 1943. The data on these animals (table 1) are included for comparison. Animals Nos. 19 and 20 exhibited low blood ascorbic-acid values even on pasture, and Animal No. 20 showed a decided decrease in plasma ascorbic acid when the feeding of this compound was discontinued.

The values for carotene (tables 1 and 2) increased greatly during the pasture season. This is in agreement with the findings of Davis and Madsen (1941) for cattle. The blood vitamin A value of the cow increases at a decreasing rate with an increased carotene level (Davis and Madsen, 1941). This was not found to be true with the horse (table 2). The level of vitamin A in equine plasma can be greatly increased by feeding shark-liver oil (Hart *et al.*, 1943). Thus, it would appear that the horse is less efficient than the cow in converting carotene to vitamin A. The normal blood level of vitamin A in the horse appears to be much lower than that of the cow in view of the findings with cattle (Davis and Madsen, 1941) and the data presented in table 2. A value of 14 micrograms percent of vitamin A is low for the cow (Davis and Madsen, 1941) but the average value for the horse (table 2) is 12.5 micrograms percent.

There is no evident correlation between the vitamin A value of the plasma and its ascorbic-acid content. This is in agreement with the findings of Hart *et al.* (1941).

The ascorbic-acid value of the mare's plasma was 0.42 ± 0.17 mg. percent for the prepasture period as compared to 0.59 ± 0.16 mg. percent for the pasture period. Thus, an increase in plasma ascorbic acid occurred with increased dietary intake of this principle. This was indicated by the earlier findings with mare's milk (Rasmussen *et al.*, 1938) and agrees with the findings of Pearson *et al.* (1943) on ascorbic-acid content of horse plasma before and after feeding ascorbic acid.

The mean value of 53.0 ± 0.17 lies within the range of 0.30 to 1.76 with an average of 0.73 reported by Errington *et al.* (1942), within the range of 0.18 to 0.86 reported by Hart *et al.* (1943), and is in good agreement with the values reported by Pearson *et al.* (1943). The values reported by Davis an Cole (1943) are considerably below this mean value.

Summary

Determinations of plasma carotene, vitamin A and ascorbic acid were conducted on horses over a period which included a change from winter to pasture rations. The mean value for carotene over the entire period was 97.0 ± 78.0 micrograms percent. The value in the prepasture period was 34.6 ± 24.6 micrograms percent, and the mean value for the pasture period was 134.9 ± 71.0 micrograms percent.

The mean vitamin A value for the plasma was 12.5 ± 3.5 micrograms percent. The comparison for the prepasture and pasture periods was 12.8 ± 3.6 and 12.5 ± 3.4 micrograms percent respectively. Thus it appears that the horse is inefficient in the conversion of carotene to vitamin A and has normal plasma values considerably below that of the cow.

The mean ascorbic-acid value for the entire period was 0.53 ± 0.17 mg. percent, and 0.42 ± 0.17 and 0.59 ± 0.16 mg. percent respectively for the prepasture and pasture periods.

No correlation was evident between plasma carotene and vitamin A or plasma vitamin A and ascorbic acid.

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CHANGES IN THE PHYSIOLOGY AND PHARMACOLOGY OF THE UTERINE MUSCLE OF THE COW IN RELATION TO THE ESTROUS CYCLE

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RECENT work upon the use of hormones in the treatment of sterility in cattle has yielded disappointing results. Accordingly, it is felt that before intelligent use can be made of these physiological agents additional information is needed on their methods of action, especially in the normal animal. A plan of research has, therefore, been undertaken upon this phase of reproduction in the cow, and this study reports the first results obtained. The general plan of these studies is to work out in more detail than has been done before the periodic changes in the histology and physiology of the reproductive tract and to ascertain to what extent these are brought about by individual hormones. It is hoped that the work will give some indication of the degree of hormonal action. The present study deals with the normal activity of the excised uterine musculature as it is modified at different stages of the estrous cycle, the relation of this activity to the size of the muscle cells, and the influence of drugs at different stages

Changes in the pattern of uterine motility during the estrous cycle have been worked out for several species. In general it may be said that proestrum and estrus are characterized by slow, even contractions of great amplitude. During the metestrous period these become more rapid and tend to be smaller, while during diestrum the contractions tend to become feeble. The change in activity appears to be related to the replacement of estrogens by progesterone or perhaps by the dominating influence of the latter. There is, however, surprising lack of agreement between species, and sometimes within species. Obviously work needs to be done upon this question especially as it may throw light upon the time at which the two hormones become active in cycles of varied duration.

The only work upon the cow seems to be that by Evans and Miller (1936) who used the balloon technic. They found marked contractions during estrus and for a few days afterwards, while contractions during the diestrous period were slight. Unfortunately the balloon technic is not sensitive enough to pick up the small contractions which seem to be characteristic of the metestrous and early diestrous periods. The excised strip method has been used in the present work because it is a more delicate indication of

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motility and because part of the plan was to obtain correlates with the histological state of the endometrium. It was felt that the irritation involved in inserting and keeping the balloon in place would introduce complications.

There seems to be no systematic work upon the effects of drugs upon the uterine musculature at different stages of the cycle in the cow.

Stieve (1926) has shown for the uterine muscle in man and Anapolsky (1928) for the tubal muscle in the sow that the length of the muscle cells varies during the cycle and that they are longest at the time that estrogenic hormones are in full action. It may be noted here that the cell length increases during pregnancy also, at a time when large amounts of estrogens are present.

Experimental

Ten heifers and one multiparous cow were used in these studies. They were picked for the regularity of their cycles which were carefully recorded. They were slaughtered at a definite stage in the cycle by a blow on the head followed by severance of the blood vessels in the neck. The abdomen was opened immediately and one side of the uterus, with its oviduct, removed and placed in about 500 cc. of oxygenated Locke's solution within 2° C. of body temperature. The uterus was then taken to a nearby laboratory and allowed to cool to room temperature, about 25°–27° C.

For the myograph studies strips of longitudinal muscle about 5 mm. thick and 4 cm. long were placed in a bath (90 cc. capacity) of oxygenated Locke's solution at 37.5° C. They were connected with a kymograph lever and allowed to work until a normal motility tracing was obtained. In the drug studies a new strip was used for each drug which was added to the bath. Return to normal activity was checked by the removal of the solution surrounding the strip and the addition of fresh Locke's solution. In some instances strips were from six to eight hours old by the time the last of the drugs was tested, but all were normally active at this time. The following drugs were tested.

Lentin[2] (carbamylcholine chloride), 1:1000 in aqueous solution; 0.1 mg. to the bath (90 cc.).

Epinephrin hydrochloride, 1:1000; 0.1 mg.

Pituitary extract, surgical strength; 0.1 or 0.2 U.S.P. units.

Arecoline hydrobromide, tablet form; 5 mg.

Atropine sulfate, tablet form; 5 mg.

Pilocarpine hydrochloride, tablet form; 5 mg.

Eserine sulfate, tablet form; 5 mg.

Gynergen[3] (ergotamine tartrate), 1:1000; 0.1 mg.

[2] Given by Merck and Company.

[3] Given by Sandoz Chemical Works, Inc.

If the amounts given above did not produce a reaction the concentration of the drug in the bath was increased.

In the studies on the length of the muscle cells, sections of tissue from the middle of the uterine horn, and, in some cases, from the tubal end also, were macerated for 22 hours in 30 percent nitric acid and then washed in tap water. The muscle layer was stripped from the mucous membrane, dropped in about 10 cc. of tap water and shaken until a fairly even suspension was obtained. This was aided by pressing the pieces of tissue against the wall of the test tube with a large glass rod. A drop of the suspension was placed on a slide and a drop of glycerol added to lessen evaporation from beneath the cover glass. The cells were measured with an ocular micrometer. Only cells which were isolated, tapered at both ends, and contained a nucleus near the center were measured. About 300 cells from each preparation were measured. A few cells appeared to contain two nuclei, a very few appeared to be split, and some were evidently contracted. Statistical precautions were taken in handling the data to determine the significance of differences.

Results

I (a) Normal uterine activity.

The types of uterine motility observed in heifers killed at definite times within the cycle were as follows.

1 day proestrum, slow even contractions of great amplitude at intervals of about 1½ minutes.

Estrus, slow contractions at 1½ minute intervals, tending to staircase and become tonically contracted.

Estrus, slow contractions at 1¾ minute intervals, tending to become tonically contracted. Some small superimposed contractions.

1 day postestrum, large even slow contractions at about 2 minute intervals with superimposed, small, more rapid contractions.

2 days postestrum, low even slow contractions at 2 minute intervals with superimposed small rapid contractions. A tendency to long regular changes in tone.

4 days postestrum, regular long changes of tonus with short, somewhat irregular changes at intervals of about ¾ minutes.

8 days postestrum, not much spontaneous activity, a tendency towards short, irregular contractions.

8 days postestrum, not much spontaneous activity.

12 days postestrum, no spontaneous activity.

16 days postestrum, little or no spontaneous activity.

2 days proestrum, slight spontaneous activity.

The motility of the uterine longitudinal muscle during proestrum, estrus and metestrum until about 2 days postestrum consists of slow, even contractions of great amplitude at from 1.5 to 2 minute intervals. During estrus and at 1 day postestrum there is a tendency for the strips in the bath to become tonically contracted for a few minutes. During the slow contractions, there tends to be a superimposed rapid small contraction at 20 to 30 seconds interval. At 2 days postestrum these small rapid contractions are more pronounced and there is a tendency for long regular changes of tonus to appear, more of a wave-like change upon which the contractions are introduced. At 4 days postestrum this tendency is more pronounced, the regular large contractions have become smaller in consequence, and the short rapid contractions have broken up the larger ones so that the impression is of irregular contractions. As the circular muscle was removed from the preparations as completely as possible it is not thought that the smaller contractions are due to this component, but the possibility must be borne in mind. The period of greatest regular activity is over well before the eggs enter the uterus. Ovulation takes place on the first day postestrum so that the eggs are probably not in the uterus until the fourth day postestrum. At 8 days postestrum there is but little spontaneous activity with some tendency for small irregular contractions to appear. At 12 and 16 days postestrum the spontaneous activity is even less, while at 2 days proestrum there is some tendency for it to reappear in the form of irregular contractions. This is the beginning of a new wave of spontaneous activity so that for the uterus proestrum consists of the first day and possibly the second day before heat.

I (b) The effects of drugs.

Pituitrin. The uterine muscle contracts and remains in tonic contraction under the influence of pituitrin at all stages of the cycle. In one of the two uteri at estrus no contraction was observed, but as this specimen had a strong tendency to remain tonically contracted, probably no further reaction was possible. Evans and Miller (1936) record that the uterus in the intact animal becomes relatively refractory to pituitrin after ovulation, which is in agreement with the reaction in most species when the uterus is under the influence of progesterone. No attempt was made in this series of observations to obtain the threshold value for pituitrin reactivity.

Epinephrin. The response to epinephrin varied with the stage of the cycle. From estrus to 4 days postestrum inhibition of the muscle was the rule; this reaction was strongly marked in one of the estrous uteri and in the one at 4 days postestrum. At 8 days postestrum one uterus showed moderate, and the other strong contractions. At 12 days there was no effect, while at 16 days postestrum, 2 and 1 days proestrum the muscle contracted. In the 2 days proestrum strip the degree of reaction varied, with some tendency for

a diphasic effect to show itself. Epinephrin is oxidized rapidly in the bath of oxygenated Locke's solution, which may affect the result at critical stages.

In general, the effect was inhibitory while the uterus was in the phase of estrogenic influence and stimulatory while it was in the progestational phase. The changes were somewhat slow in development compared with most other effects of the two ovarian hormones, e.g. with changes in the size of muscle cells and with changes in the endometrium.

Reynolds (1939) has summarized the reactions to epinephrin, classing species into three groups according to the uterine response. Group I, the 'rabbit' group responds with a motor effect in both gravid and non-gravid states; group II, the 'guinea pig' group responds with inhibition in both states; group III, the 'cat' group (the cat and dog are the only species yet included) responds with inhibition in the non-gravid and with motor effects in the gravid state. According to the reactions during the cycle the cow falls into group III. This conclusion is confirmed by Sommer (1932) who recorded epinephrin contractions during pregnancy. One of his illustrations also shows a transient response when a 'non-functional' corpus luteum was present.

Parasympathomimetic drugs—Lentin. The drug, lentin (carbamylcholine chloride), produced tonic contractions at all states of the cycle. The reaction appeared to be stronger at from 8 days postestrum to 2 days proestrum.

Arecolin produced tonic contractions at all stages with a tendency for them to be stronger at mid-cycle. The reason for the strength of the contractions at this time, both with lentin and arecolin, may be that there is little spontaneous activity, enabling the drugs to act upon the muscle at a lower base level. It would be interesting to determine whether a differential threshold exists for these drugs similar to that for pituitrin, especially as other parasympathomimetic drugs are without much effect.

Gynergen (ergotamine tartrate) was without effect upon the uterine muscle, except perhaps at 8 days postestrum when a slight positive reaction was obtained in both specimens. At 1 day postestrum there was a tendency for the rapid contractions to increase in amplitude, but this was not observed at any other time.

Pilocarpine. The effect of this drug was most variable. Positive reactions were observed at 1 day, 4 days and 8 days (one specimen) postestrum and at 1 day proestrum. At 2 days proestrum it tended to increase the rate of contraction and at 15 days postestrum it may have slightly increased the contractibility of the muscle. However, these effects were small.

Eserine was mainly without effect. At 8 and 16 days postestrum it produced a slight contraction, which was, however, somewhat doubtful in the latter case as the 5 mg. dose was without effect, while the addition of a further 5 mg. was followed by a very irregular effect quite unlike the usual response of a uterine strip to a stimulating drug.

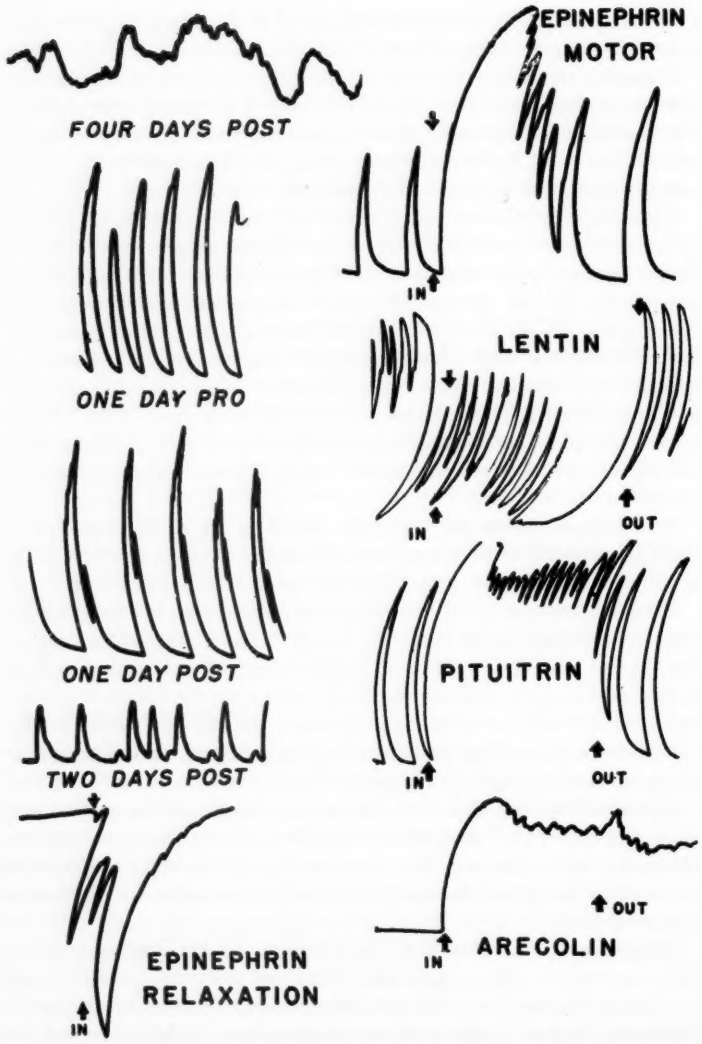

Figure 1. Spontaneous contractions of uterine muscle strips; four days after heat, one day before heat, one day after heat, two days after heat. Response to epinephrin, relaxation during heat and contraction one day before heat. Effects of other drugs; Lentin, strong contractions. Pituitrin, strong tonic contractions. Arecolin, strong tonic contractions.

Atropine, a parasympathetic inhibitor, was without effect except at 8 days postestrum when some inhibitory tendency was observed.

The effects of the parasympathomimetic drugs thus were variable. Lentin and arecolin caused strong contractions at all stages of the cycle, while gynergen, pilocarpine and eserine had little or no effect, and atropine produced no inhibition. The conclusion is drawn that the parasympathetic nervous system is without influence upon the uterine musculature of the cow, and that lentin and arecolin produce their effects through some other mechanism, probably, as pituitrin is believed to do, by direct action upon the cell.

II. The size of the muscle cells.

The measurements of the uterine muscle cells with their statistical treatment are given in table 1. The curves for most of the heifers were essentially normal or slightly skewed to the negative side. This slight negative skew-

TABLE 1. AVERAGE LENGTHS OF UTERINE MUSCLE CELLS.

Stage of of the cycle	Region of horn	Av. length of cells, micra	Modal lenght, micra	Standard deviation, micra	Standard error of mean, micra	Skewness
2 days proestrum	tubal end	98.6	85.7	23.0	1.12	+0.561
	middle	87.1	85.7	21.7	1.06	+0.065
1 day proestrum	middle	112.3	114.3	21.2	1.03	−0.094
Estrus	tubal end	110.8	107.1	22.9	1.12	+0.162
	middle	106.6	92.8	25.0	1.21	+0.522
Estrus	tubal end	95.1	94.3	19.1	1.90	+0.042
	middle	72.2	71.4	15.2	1.45	+0.049
1 day postestrum	middle	98.3	99.9	20.3	1.00	−0.079
2 days postestrum	middle	128.5	128.6	31.0	1.51	−0.003
4 days postestrum	middle	92.2	92.8	21.0	1.02	−0.286
8 days postestrum	middle	119.7	121.4	25.5	1.24	−0.066
8 days postestrum	tubal end	67.3	65.7	13.5	1.29	+0.114
	middle	72.9	71.4	15.8	1.48	+0.094
12 days postestrum	tubal end	85.8	71.4	19.3	0.94	+0.746
	middle	85.4	85.7	19.0	0.93	−0.016
16 days postestrum	middle	81.7	78.6	15.5	0.77	+0.200

ness may have been caused by an excessive breakage of the longer cells so that fewer of them were measured, though, as it was observed mainly during the involution of the tract, it may well represent a real deficiency of the longer cells. The uteri with cells whose distribution was positively skewed were, with one exception (8 days postestrum), taken from animals killed in the late diestrous, proestrous or estrous stages. This strongly suggests that it is an indication of the growth which was beginning or in progress. The degree of skewness was, in general, greater in specimens from the tubal end which suggests a growth gradient starting from the apex of the horns. The degree of the skewness was greater at the apex throughout the growth period until the day of estrous when it was reversed in both specimens. Apparently the growth impulse has by that time spent itself in the apical region, but is still effective towards the cervix.

There is considerable variation in the average length of the cells at different stages, but there is a strong tendency for them to be longer at the time of heat, when the estrogenic hormones may be expected to be most active. They are smallest about the end of the diestrous period and renewed growth begins about 2 days proestrum or a little before. They are certainly at their longest when the degree of spontaneous activity is greatest. This is in accord with the results of Anapolsky (1928) for the tubal muscle of the sow and in general accord with those of Stieve (1927) for the uterine muscle in man.

One of the heifers killed at 8 days postestrum had unusually long cells, quite out of accord with the rest of the data.

Discussion

It is not proposed at this time to offer any general discussion on the estrous cycle of the cow and the changes which occur therein as much data from other parts of the reproductive tract must be considered in connection with the changes now recorded. Discussion of causes must also await further experimental work. A few conclusions and some suggestions for further work have been made in connection with the detailed results. All that can be done at present is to point out that the activity and growth which occur in the uterine muscle cannot have much influence upon the egg as it enters the uterus at a relatively quiet period, when the cells are decreasing in size. The activity during estrus may help in the distribution of semen throughout the uterus by spreading it in a thin layer but this is purely speculative as are most of the other theories of sperm transport. The influence of estrogens is shown in many ways and uterine contractility and growth are important at the proper time. It still remains to be shown that the effects upon the muscle at the time of heat serve a useful purpose and are more than coincidental.

Summary

Studies were made upon excised uterine muscle of cattle killed at known stages of the estrous cycle.

Spontaneous motility is greatest during proestrum and estrus, becomes irregular during metestrum and dies down during diestrum.

The motility consists of two types of waves, strong contractions of great amplitude at intervals of 1½ to 2 minutes and small contractions at 20 to 30 second intervals. The latter increase in importance during metestrum and are a large factor in the production of the irregularity. In early diestrum long rhythmic changes of tone also occur.

Pituitrin, arecolin and lentin produce strong tonic contractions at all stages of the cycle. Eserine, gynergen and pilocarpine have very irregular effects and are mainly inert. Atropine rarely produces an inhibitory effect.

Epinephrin is inhibitory during and shortly after the estrogenic phase, and motor during the progestational phase. The cow thus falls into group III, the 'cat' group in respect to this effect.

The muscle cells of the uterus grow in length during the estrogenic phase and decrease in length during the rest of the cycle. The growth impulse starts at the apices of the uterine horns and travels caudally. It is over at the apices earlier than it is in the rest of the tract.

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A COMPARATIVE STUDY OF EPIDIDYMAL AND EJACULATED SPERMATOZOA OF THE BOAR

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THE comparative study of certain characteristics of epididymal and ejaculated spermatozoa was stimulated by the observation that the fertilizing capacity of spermatozoa in the isolated epididymis may be maintained up to 40 days (in the rabbit, Hammond and Asdell, 1926), while that of ejaculated spermatozoa stored "in vitro" may be maintained for only a few hours in some species (boar and stallion) and for only a few days in others (ram and bull). The literature concerning this noteworthy difference in the retention of fertilizing capacity suggests three possible explanations: (1) conditions in the epididymis are optimum for storage and, consequently, spermatozoa survive there for a maximum period of time; (2) optimal storage conditions "in vitro" are not provided, and as a result spermatozoan survival is limited; and (3) spermatozoa go through certain changes as they pass through the reproductive tract which reduce their ability to survive under storage conditions. Since the optimal storage conditions in the epididymis may be the result of an indirect action of the male sex hormone (Moore, 1928), it may be impossible to duplicate these epididymal conditions "in vitro." However, if the differences in survival during storage of epididymal and ejaculated spermatozoa are due to physiological or morphological changes in the spermatozoa, it may be possible to prolong the storage period of ejaculated spermatozoa by preventing these changes or reversing them immediately following ejaculation.

The data in this paper pertain to characteristics of epididymal[2] and ejaculated spermatozoa which may indicate whether or not spermatozoa undergo detrimental changes during their passage through the male reproductive tract.

Materials and Methods

The material for these studies was obtained from 20 boars ranging from 6 to 24 months of age. The boar was used because of the large volume of the ejaculated semen produced and the large number of spermatozoa present in its epididymis. Semen was collected from the boar immediately before re-

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[2] Spermatozoa obtained from the epididymis suspended in fluids from the epididymis and testis and the phosphate buffer used in their collection.

moval of the epididymis by castration, thus making possible a study of epididymal and ejaculated spermatozoa from the same animal.

Semen was collected with an artificial vagina. The epididymal spermatozoa were obtained by two different methods. In the first, the vas deferens was dissected from the surrounding material, washed free of blood and then placed with the open end in a clean container. The tubule next to the body of the epididymis was next dissected free of the covering membrane (tunica

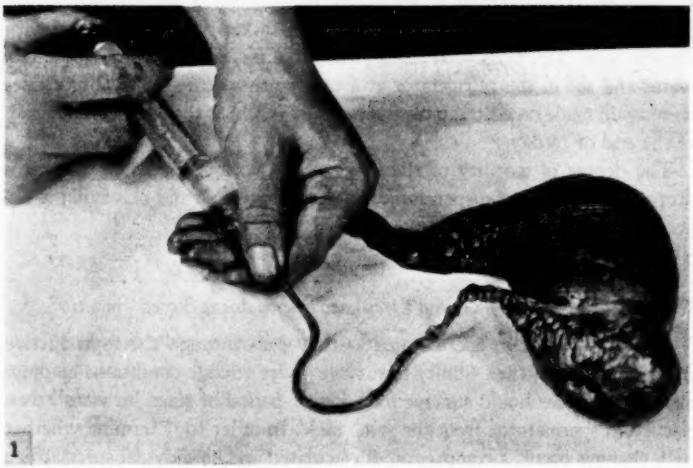

Figure 1. Showing how spermatozoan suspensions were obtained from the epididymis by injecting buffer into the vas deferens and distending the epididymis.

albuginea) and a phosphate buffer solution (pH 7.20) was injected into it through a 24 gauge needle attached to a 25 cc. syringe. Injection of the buffer was continued until the majority of the spermatozoa was forced from the epididymis. A second method used in later experiments was a modification of that described by Czarnetzky and Henle (1938) in which the diluter was forced from a syringe into the vas deferens until the epididymis was greatly distended (figure 1). An incision was then made in the region of the distended tubule nearest the testis and the spermatozoa were forced into a clean container. The latter method is the simpler and makes possible the recovery of a larger portion of the spermatozoa. The use of either method, if carried out carefully, makes it possible to secure a pure spermatozoan suspension containing little or no blood and tissue fluids.

The percentage of live spermatozoa was determined in each sample immediately after collection by the opal blue-eosin technique described for ram semen by Lasley, Easley and McKenzie (1942) and modified for use on bull semen by Easley, Mayer and Bogart (1942) and by Lasley and Bogart (1943). Two slides were made of each sample and 500 spermatozoa were counted on each slide. Resistance tests were made by subjecting 1 cc. of the spermatozoan suspension to a temperature of 0°C. for 10 minutes, after which duplicate slides were again made to determine the percentage of live spermatozoa. For storage, 1 cc. samples of semen and of epididymal spermatozoa in suspension as collected were placed in 4 cc. vials, corked tightly, and sealed with paraffin wax. The vials were then placed in a beaker containing 300 cc. of water and set in the refrigerator at a temperature of 10–12°C. Two slides were again made on each sample (warmed to 35°C.) at the end of 6 and again at the end of 16 days.

The degree of motility of the spermatozoa was estimated by placing a drop of spermatozoan suspension on a glass micro-slide and observing it under the microscope with low power.

Results

The Survival of Epididymal and Ejaculated Spermatozoa Stored "in vitro"

If changes occur in spermatozoa as they pass through the reproductive tract which lower their ability to survive under storage conditions epididymal spermatozoa should survive for a longer period of time "in vitro" than ejaculated spermatozoa from the same male. In order to determine whether such changes occur, a comparison of ejaculated and epididymal spermatozoa from several different boars was made by storing them for periods of 6 and 16 days. The spermatozoa from the epididymides were stored as collected. They were in a medium composed of epididymal fluids and diluted slightly by the phosphate buffer used in their collection. Although the concentration of epididymal spermatozoa in fluids from the epididymis was about ten times that of semen, studies to be reported elsewhere show that the concentration of spermatozoa was not a factor in survival.

The results (table 1) show that an average of 75 percent of the epididymal spermatozoa were alive at the end of 6 days whereas only 44.8 percent of the ejaculated spermatozoa survived this period, even though the two types of spermatozoa were stored under similar conditions. The difference in survival was even greater after a storage period of 16 days when an average of 51.2 percent of the epididymal spermatozoa were still alive as compared to only 9.6 percent of the ejaculated spermatozoa. Approximately the same percentage of epididymal spermatozoa were alive after a storage period of 16 days as that of ejaculated spermatozoa stored for only 6 days. It has been shown

(Lasley and Bogart, 1944) that ejaculated spermatozoa in epididymal fluids have the same resistance as those in semen as ejaculated and that epididymal spermatozoa in semen plasma survive during storage and have the same resist-

TABLE 1. THE PERCENTAGE OF LIVE SPERMATOZOA IN THE EPIDIDYMIS AND NORMAL SEMEN OF THE BOAR AFTER A STORAGE PERIOD OF 6 AND 16 DAYS

Breed and number of boar	Epididymal spermatozoa		Normal semen	
	% Live sperm, 6 Days	% Live sperm, 16 Day	% Live sperm, 6 Days	% Live sperm 16 Days
Hamp. 1	63.0	—	38.0	—
P.C. 113	86.0	—	57.0	—
C.W. 1*	48.0	—	12.0	—
P.C. 91	50.0	40.0	29.0	9.0
P.C. 53	89.0	45.0	70.0	0.0
P.C. 63	91.0	51.0	49.0	22.0
Hamp. 73	87.0	45.0	67.0	3.0
P.C. 160	86.0	75.0	36.0	14.0
Averages	75.0	51.2	44.8	9.6

ance as epididymal spermatozoa in epididymal secretions. One therefore might conclude that the difference in survival of epididymal and ejaculated spermatozoa resides in the cells rather than in the medium in which they are suspended.

Characteristics of Epididymal and Ejaculated Spermatozoa which Might Influence Survival Capacity

Since the storage results (table 1) indicate that spermatozoa in ejaculated semen survive for a shorter time than epididymal spermatozoa, a comparative study of certain characteristics of epididymal and ejaculated spermatozoa such as morphology, motility, percentage of live and percentage of resistant spermatozoa is necessary.

Morphology. The morphological characteristics of spermatozoa from the epididymis of the boar differed from those of spermatozoa in the ejaculated semen. The chief difference was the presence of a protoplasmic droplet on the mid-piece of epididymal spermatozoa. This droplet was found on nearly all the spermatozoa obtained from the epididymis, and its position on the spermatozoa varied somewhat with the part of the epididymis from which the spermatozoa were obtained. In spermatozoa from the head of the epididymis, the protoplasmic droplet was located immediately behind the spermatozoan head (figure 2), while in spermatozoa from the body and tail of the epididymis and from the vas deferens, the droplet was usually attached

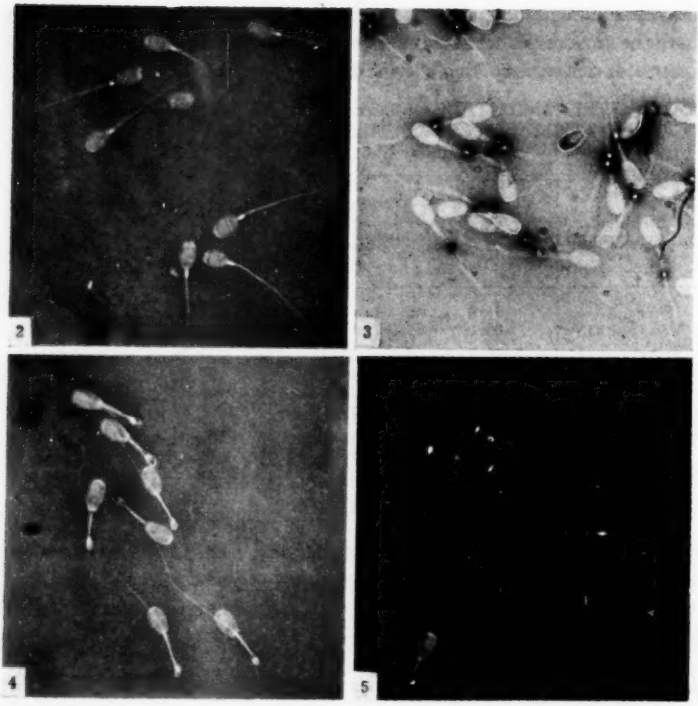

Figure 2. Spermatozoa from the epididymis of the boar. A protoplasmic droplet is located immediately behind the head of the spermatozoa from the head of the epididymis.

Figure 3. Spermatozoa from the epididymis of the boar. A protoplasmic droplet is attached to the posterior region of the mid-piece of spermatozoa from the tail of the epididymis and the vas deferens.

Figure 4. Bent tails at region of protoplasmic droplet in spermatozoa from the tail of the epididymis and the vas deferens.

Figure 5. When the protoplasmic droplet was immediately behind the head of the spermatozoa as in those from the head of the epididymis no bend in the tail occurred.

to the posterior region of the mid-piece (figure 3). As a general rule, the protoplasmic droplet was found only on a small number of ejaculated spermatozoa, but when present, it was generally located on the posterior portion of the mid-piece.

Ejaculated spermatozoa showed no change in morphology even after a storage period of several days. On the other hand, spermatozoa from the tail

and the body of the epididymis and from the vas deferens stored "in vitro" for only a few hours showed definite changes in morphology. The majority of these spermatozoa had bent tails at the region of the protoplasmic droplet

TABLE 2. PERCENTAGE OF LIVE SPERMATOZOA IN THE EPIDIDYMIS AND IN EJACULATED SEMEN OF THE BOAR.

Breed and number of boar	% Live sperm, tail of epididymis	% Live sperm, normal semen
Hamp. 1	88.0	50.0
C.W. 1	95.0	70.0
P.C. 113	93.0	81.0
P.C. 91*	65.0	56.0
P.C. 53	95.0	86.0
P.C. 63	93.0	83.0
Hamp. 73	97.0	92.0
P.C. 160	98.0	60.0
P.C. 54	93.0	93.0
P.C. 13	93.0	86.0
Averages	91.0	75.7

* Many of the spermatozoa were abnormal in morphology.

(figure 4), whereas spermatozoa obtained from the head of the epididymis did not show any change in morphology unless the protoplasmic droplet was attached to the posterior region of the mid-piece (figure 5). Therefore, it appears that the bending of the tails of the spermatozoa during storage was closely associated with the position of the protoplasmic droplet.

Motility. Only slight motion was observed in spermatozoa obtained from the epididymis. The degree of motility[3] was usually rated as 1 or 2. There was little visible difference in the degree of motility of the spermatozoa from the different levels of the epidydmis. Ejaculated spermatozoa were highly motile and could usually be given a rating of 4 or 5.

The addition of centrifuged semen plasma to epididymal spermatozoa increased motility slightly in some cases, but it was never as great as that of ejaculated spermatozoa.

The addition of 0.9% NaCl or phosphate buffer solution to epididymal spermatozoa brought about no visible change in motility. However, the addition of 0.1% of strychnine sulphate to either solution greatly increased spermatozoan motility. Epididymal spermatozoa activated by the strychnine solution did not show the same strong, forward motion as ejaculated spermatozoa, but displayed a strong vibratory motion.

Percentage of Live Spermatozoa. Although little motion was displayed at

[3] Motility rating of 0 to 5 in which 0 represents no motility and 5 the greatest motility.

the time of collection by epididymal spermatozoa, a large percentage of them were alive as determined by the opal blue-eosin staining method (table 2). There was an average of 91 percent live spermatozoa obtained from the

TABLE 3. THE PERCENTAGE OF SPERMATOZOA SURVIVING A COLD SHOCK IN THE EPIDIDYMAL SUSPENSIONS AND IN NORMAL SEMEN OF THE BOAR.

Number of boar		Percentage of live sperm 10 minutes at 0° C., tail of epididymis	Percentage live sperm 10 minutes at 0° C., ejaculated sperm
Hamp.	1	45.0	5.0
C.W.	1	46.0	4.0
P.C.	113	75.0	14.0
P.C.	91	41.0	12.0
P.C.	53	75.0	6.0
P.C.	63	72.0	21.0
Hamp.	73	87.0	20.0
P.C.	160	76.0	24.0
P.C.	54	69.0	5.0
P.C.	13	64.0	14.0
Averages		65.0	12.5

epididymides of 10 boars as compared to an average of 75.7 percent live spermatozoa in the ejaculated semen of the same individuals.

The results in table 2 show that approximately 15 percent of the spermatozoa died during their passage from the epididymis into the ejaculated semen.

Resistance to a Cold Shock. Epididymal spermatozoa were more resistant to a cold shock than were ejaculated spermatozoa from the same boar (table 3). An average of 65 percent of the spermatozoa from the tail of the epididymis were alive after 10 minutes at 0°C., while only 12.5 percent of the spermatozoa in the semen survived this treatment. The degree of resistance of bull spermatozoa to a cold shock is closely related to the ability of these spermatozoa to survive under storage conditions (Lasley and Bogart, 1943; Lasley and Mayer, 1944), and this may also be true of boar spermatozoa.

Discussion

The results reported herein show that epididymal spermatozoa and those in ejaculated semen differ in several characteristics and indicate that morphological and other cellular changes rather than environmental changes are factors contributing to these differences.

It has been shown (table 1) that epididymal spermatozoa survive for a longer period of time "in vitro" than do ejaculated spermatozoa from the

same male when stored under similar conditions. A comparison of certain characteristics of epididymal and ejaculated spermatozoa of the boar revealed dissimilarities which may be associated with the difference in their survival during storage. Morphological differences consisted primarily of the presence or absence of a protoplasmic droplet. The protoplasmic droplet was usually absent from ejaculated spermatozoa, but was present on the majority of epididymal spermatozoa. In the latter its position varied on spermatozoa from different levels of the epididymis. Although some authors have concluded (Redenz, see Allen *et al.*, 1939; Roemmele, 1927; and, Lagerlof, 1936) that spermatozoa possessing this droplet are immature, Selivanova, (1937) was of the opinion that the change in position of the droplet was no criterion of maturity, but its disappearance from ejaculated spermatozoa was caused by a change in the composition of the surrounding secretions. At present, it is not known whether the loss of the droplet in ejaculated spermatozoa is detrimental to their ability to survive under storage conditions. Merton (1939) reported that the presence of the droplet was necessary for the survival of mouse spermatozoa taken from the epididymis, but its loss was not harmful to mature or ejaculated spermatozoa.

In this investigation the spermatozoa which have the protoplasmic droplet on the posterior portion of the mid-piece show a sharp bend at this region during storage. Ordinary stains do not reveal the protoplasmic droplet, therefore, in most semen examinations for abnormalities in morphology, this droplet would not be seen when present. By use of the opal blue-eosin stain the protoplasmic droplet is clearly visible. Since the protoplasmic droplet is present on most spermatozoa in the head of the epididymis and is usually lost by the time the spermatozoa become a component of semen and there is a definite bending of the tail associated with this protoplasmic droplet after a short storage period, it appears that the spermatozoa showing this bend should be considered as immature or underdeveloped. This abnormality could result from too frequent use of a male in either natural or artificial breeding or to some physiological disturbance in spermatogenesis.

Epididymal and ejaculated spermatozoa of the boar differed greatly in motility. Spermatozoa taken from different levels of the epididymis showed slight motility, while ejaculated spermatozoa were highly motile. The motility of epididymal spermatozoa was slightly increased by the addition of plasma from centrifuged semen, but never approached that of ejaculated spermatozoa. Since the addition of a dilute solution of strychnine sulfate to epididymal spermatozoa greatly increased their activity, it appears that these cells are capable of motion although motility was of a rapid vibratory nature rather than progressive as in ejaculated spermatozoa.

It is possible that changes resulting in the increased motility of ejaculated

spermatozoa may reduce their ability to survive under storage conditions. However, this phase of the problem requires a more detailed study.

In table 2 it is shown that 15 percent more live spermatozoa are present in the epididymis than in the ejaculated semen. Since there is a larger percentage of live spermatozoa in the epididymis at the beginning, this might partially explain the ability of boar epididymal spermatozoa to survive for a longer period of time under storage conditions.

The decrease in resistance of spermatozoa as they pass through the reproductive tract into the ejaculated semen was closely correlated with the ability of the spermatozoa to survive under storage conditions. This correlation is in agreement with the results of Lasley, Easley and Bogart (1942) and Lasley and Mayer (1944) showing a high correlation between the resistance of ejaculated bull spermatozoa and their ability to survive "in vitro." The great difference in the resistance of ejaculated and epididymal spermatozoa arouses considerable speculation as to the explanation. Theoretically, the resistance of epididymal spermatozoa could be greater because of some action of the epididymal secretion similar to that described by Lasley, Easley and Bogart (1942) who found that egg yolk buffer solution increased the resistance of bull spermatozoa as much as 500 percent. Redenz (1929) contends that spermatozoa are surrounded by a minute protective film obtained from the secretions of the epididymis. His observations indicate that spermatozoa become more "resistant" as they move from their place of production due to this protective film. The observations of Young (1929) do not support Redenz's contention. Our work would suggest that if a protective material is present in the epididymal fluids, ejaculated spermatozoa have lost their ability to make use of this protection since ejaculated spermatozoa suspended in epididymal fluids were no more resistant than those in semen plasma. It may be that the accessory secretions decrease resistance through dilution or enzymatic action. Popa (1930) set forth the theory that spermatozoa are protected by a lipoid mantle, which he was able to detect by osmic acid, Sudan, and Schumacher's method for detecting lipoid substances. According to Popa, as long as the lipoid mantle is not changed in its composition the spermatozoa remain inactive, but when the spermatozoa are suspended in the accessory secretions the lipoid mantle is destroyed and movement appears. It is possible, therefore, that the accessory secretions destroy the lipoid mantle and change the resistance of the spermatozoa. However, when epididymal spermatozoa were suspended in semen plasma they were as resistant and survived as long as those suspended in epididymal fluids.

Hence, all changes resulting in the lowered survival of ejaculated spermatozoa appear to be of a cellular nature and independent of the fluid in which they are suspended.

Conclusions

1. Results reported in this paper show that epididymal spermatozoa differ from those in ejaculated semen and indicate that morphological and other cellular changes rather than environmental factors contribute to this difference.

2. Spermatozoa from the epididymis of the boar stored "in vitro" remained alive for a longer period of time than spermatozoa in ejaculated semen from the same male.

3. The resistance of spermatozoa to a cold shock differed with the part of the reproductive tract from which the spermatozoa were obtained; those from the epididymis were much more resistant than were ejaculated spermatozoa.

4. Differences in several characteristics of epididymal and ejaculated spermatozoa exist and the lower survival of ejaculated spermatozoa during storage seems to result from changes within the cells themselves rather than differences in the fluids in which they are suspended.

5. A protoplasmic droplet was present on the midpiece near the head of the spermatozoa obtained from the head of the epididymis, on the posterior part of the midpiece of spermatozoa obtained from the tail of the epididymis and the vas deferens, and was absent in ejaculated spermatozoa.

6. There seemed to be a relation between the position of the protoplasmic droplet and the bending of the tails of spermatozoa during storage. It is suggested that spermatozoa showing bent tails are undeveloped ones which may result from over use of the male or from a disturbance in spermatogenesis.

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PRELIMINARY REPORT ON CROSSING OF INBRED LINES OF SWINE[1]

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IT HAS been demonstrated that the crossing of breeds of swine is frequently accompanied by increased (hybrid) vigor (Winters, *et al.*, 1935, Lush *et al.*, 1939, and Hutton and Russell, 1939 and others). It is an established fact that the crossing of two inbred strains of corn or laboratory animals usually results in the production of offspring with increased vigor.

Inbred lines of farm animals, comparable to those used in studies of corn and laboratory animals, have not been available for studies of crossbreeding. Eaton (1941) studied the effects of crossing inbred lines of guinea pigs and generalized rather despairingly about the difficulties likely to be encountered in establishing inbred lines of farm animals and the advantages to be derived from their use in crosses. Wright (1922) reported favorable results from the crossing of inbred lines of guinea pigs, on the basis of which he recommended the improvement of farm animals through the development of inbred lines and the subsequent crossing of the same.

Since 1937 work in the development of inbred lines of swine has been under way at several state experiment stations through cooperation with the Regional Swine Breeding Laboratory (Craft, 1943, and Winters *et al.*, 1943).

The experiments reported are for the most part preliminary trials to sample what might be expected from certain crosses. They are reported at this time because of the general interest in the practical possibilities of inbred lines and because the results when put together are in accordance with genetic theory and those from related experiments (the crossing of outbred swine and the crossing of inbred strains of corn and laboratory animals).

Procedure

These crosses were carried out over a three year period. Seven inbred lines were used to make eight different line crosses within the Poland China breed, and three lines belonging to three different breeds were used to make five crosses between breeds. One of the lines used in a breed cross was developed by the Oklahoma Agricultural Experiment Station; all the other lines were developed by the Minnesota Agricultural Experiment Station. None of the inbred lines, with the possible exception of the Minnesota M line

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(F_x., .72), were far advanced in inbreeding as compared to inbred lines of corn and laboratory animals. They do, however, possess considerably more inbreeding than outbred swine of the breeds represented.

As already mentioned the experiments, for the most part, were what may be termed pilot experiments; hence in several of them the numbers were small and the controls not as complete as desired. In several instances one of the parental strains was reared under a different environment from that of the crossbreds. In every instance where data are taken on parental lines reared at a location other than that of the crossbreds, data on the performance of the inbred lines gathered during years that the environemnt was unfavorable were rejected and replaced by averages of several years' performance. This was done so as not to give any possible advantage to the cross breds in the comparisons.

Four of the experiments were carefully planned. Samples of both inbred lines were raised alongside the crossbreds; gilts only were used as dams; and it was planned to use two or more sires from each line. The specific plan was:

Boars		Gilts for production of			
Individual designation	Line	(1) Pure lines		(2) Crosses	
		No.	Line	No.	Line
1	I	2	I	1	II
2	I	2	I	1	II
3	II	2	II	1	I
4	II	2	II	1	I
Total 4		8		4	

Unfortunately it is seldom possible to conduct breeding experiments with farm animals with the precision desired and planned. Several of the obvious reasons are males' refusals to work on the specific days needed, females' failures to settle, and sickness and death among females after settling.

It is surprising, however, how little difference there is in the results when the experiments are divided and summarized according to those that were well planned and those that were mere pilot experiments. The results in both cases point in the same directions and are remarkably consistent. (This is not to be construed as defense for loosely planned and executed experiments but merely as an explanation for the methods employed in handling and presenting these data.)

Data and Discussion

Table 1 contains the summarized results of all the crosses within and be-

tween breeds. It should be noted that both types of line crosses, within and between breeds, showed an increase of vigor in every item of comparison.

Data on economy of gains are not included because they were not gathered on the fall pigs; nearlyall of the data on line crosses between breeds were gathered on fall pigs. It also appears that all data in the project on economy of gains will require an exhaustive study of the factors affecting economy of gains before making critical comparisons. It is obvious that with a

TABLE 1. SUMMARY OF LINE CROSSES WITHIN AND BETWEEN BREEDS

	No. of crosses and samples of lines	No. of litters	No. of pigs	F_x of pigs	Average no. born alive per litter	Average no. weaned per litter	Average per cent death loss	Average weight, lbs. at 56 days	Average weight, lbs. at 180 days	Average rate of gain weaning to 200 lbs.	Average score
Crossed Poland China lines	8	33	249	7	7.56	6.76	12	36	238	1.53	47
Inbred Poland China lines	16	157	1105	35	7.04	5.48	22	32	214	1.38	43
Crossed line advantages				−28	.52	1.28	10	4	24	.15	4
Crossed lines of different breeds	5	13	94	00	7.20	6.23	15	41	254	1.62	46
Inbred lines of three breeds	10	212	1509	47	7.12	5.56	21	30	189	1.25	37
Crossed line advantages*				−47	.08	.67	6	11	65	.37	9

* All these crosses were made using females of the line low in fertility and milk production.

fixed age for weaning, the faster gaining pigs will wean at heavier weights than the slower gaining pigs. It appears that even when an attempt is made to remove animals from test within a narrow range of weights, there is a tendency to allow the faster-gaining animals to reach heavier weights than the slower-gaining animals. This suspected tendency can only be verified or rejected by a complete study of all data in the project bearing on this point. If this suspected tendency is true, it will add to the effect of heavier weaning weight in having an additional unfavorable effect on the economy of gains for fast gaining pigs as calculated from uncorrected records. This is due to the fact that the relative maintenance requirements increase with increased weight. How much effect use of uncorrected records may have can be determined only by a thorough study of a large amount of data. Knapp and Baker (1943), however, concluded from a study of performance in

steers " . . . that in a time constant population where animals are not the same size, selections should be made on rate of gain rather than on observed gross efficiency."

Measures of performance. In comparing the performance of hybrid corn with the parental strains or with standard varieties, yield per acre makes an easy method of comparison. No one single measure of performance in swine is comparable to yield per acre in corn. Performance affecting economy of production in swine may be reduced to five basic factors, namely:

1. Fertility—number of pigs born alive
2. Survival
3. Rate of gain
4. Economy of gain
5. Score for body conformation—ability to satisfy market requirements

In this connection it is worthy of note that corn breeders also find it useful to appraise performance on the basis of several contributing factors.

The above five factors undoubtedly differ in relative economic importance, but since their relative values have not been determined, they are taken as equal in this appraisal of vigor. Knapp and Baker's (1943) suggestion regarding estimating relative economy of gain from rate of gain was accepted and rate of gain in the feed lot was used in place of economy of gains. Rate of gain from birth on is important in commercial production; hence 180-day weight is used for rate of gain.

Advantages in terms of percent. In each of the 13 experiments the advantage or disadvantage of the crossbreds in comparison with the average of the parental stock was calculated for each of the above mentioned five factors in terms of percent. The results were added for each cross and divided by five to give the overall advantage or disadvantage in performance for each group of crossbreds. By this method of comparison 12 of the 13 crosses possessed more vigor than the average of the parental lines.

Decrease in inbreeding and increase in vigor. The crosses were then grouped according to the decrease in the coefficient of inbreeding of the crossbreds. (Some of the inbred lines were related.) The superiorities of the crosses are expressed in percentages and given in table 2. The same data are regrouped according to the coefficient of inbreeding remaining in the crossbred pigs and the results are also presented in table 2.

For the small amount of data available it is surpsiring how regularly the decrease in inbreeding is accompanied by an increase in vigor. In like manner the actual coefficient of inbreeding of the pigs corresponds nicely to the increase in vigor of the crosses. The line crosses between the breeds showed more increased vigor than the line crosses within a breed. The results show an advantage of genetic diversity between parental stocks and in this respect

they correspond closely to conclusions from the crossing of corn by Johnson and Hayes (1940) and the crossing of poultry by Maw (1941).

TABLE 2. WIDTH OF CROSS AND PERCENT INCREASE IN VIGOR OF CROSSBREDS (FIVE MEASURES OF VIGOR)

a. Decrease in F_x	17	31		50	Line crosses between breeds
Increase in vigor, %	9	10		13	19
b. F_x of pigs produced	15	0 (Line crosses within Poland China)			0
Increase in vigor of crossbreds, %	9	12			19

Use of inbred lines and outbred stock in crosses. An attempt was made to compare the advantages of crosses involving inbred lines with crosses between non-inbred purebreds. For this purpose the data on breed crosses by Winters *et al.* (1935) were put on the same basis as the data in table 2 with the exception that score was not available. The data on line crosses were recalculated on the same basis, score omitted, and the results are given in table 3.

TABLE 3. INCREASE IN VIGOR IN INBRED LINE CROSSES AND OF NON-INBRED BREED CROSSES (FOUR MEASURES OF VIGOR)

Cross	Advantage, %
Outbred breed crosses	
First cross	6.3
Back cross	7.5
Three breed cross	11.7
Line crosses	
Within breed	10.6
Between breeds	19.9

The increased vigor in breed crosses over line crosses within a breed, wherein the coefficient of inbreeding decreased 50 percent (table 2a), is the same as that shown by crosses of non-inbred breeds (table 3). The increased vigor in crosses between lines of different breeds over the increased vigor of line crosses within a breed wherein the crosses have no inbreeding left (table 2b), excepting that existing in the breed as a whole, is also essentially the same as that which resulted from the crossing of breeds, using non-inbred stock (table 3). In the above comparisons five measures of vigor were taken in one case and four in the other, but a comparison of tables 2 and 3 reveals

that use of four measures made only slight changes in the percentage increases of vigor.

On the basis of the increase of vigor proportionate to the decrease in inbreeding exhibited by the line crosses within the Poland China breed (table 2), it can be estimated that breed (non-inbred) crosses (table 3) result in a decrease in inbreeding of about 10 percent. As it happens this is the same figure given by Lush and Anderson (1939) as an estimate of the coefficient of inbreeding for the Poland China breed.

The above offers an interesting and what may later prove a useful method of arriving at the genetic differences between the breeds. As information on line crosses accumulates from the various institutions developing inbred lines, estimates of this kind should become much more reliable. It would be highly desirable if facilities would permit experiment stations to carry on crossing experiments between the breeds using outbreds simultaneously with the crossing of the inbred lines. This would not only allow a more accurate appraisal of the value of the inbreds for crossing purposes but it would permit arriving at rather reliable estimates of the genetic differences between the breeds. This information undoubtedly would later prove useful in predicting the to be expected successes of line crosses between breeds.

Performance of line-crosses and performance of selected outbreds. The practical question is not how much advantage the crosses show over the inbred lines but how they compare in performance to good non-inbred swine. It would be desirable to carry adequate numbers of non-inbreds as checks much as is done in testing the merits of hybrid corn. The authors hesitate to advance an estimate of what would constitute an adequate check from a sampling of the breeds, but are inclined to believe the requirements would be out of all proportion to facilities now available. At any rate no non-inbreds were maintained for this purpose, but another method of making comparisons was used; the performance of the crosses was compared to the performance of what is believed to be the performance of superior outbreds reared under favorable conditions. Comparisons were possible only on average number weaned, weaning weight, rate of gain, and 180 day weight. Data on number weaned and weaning weight are taken from Lush and Molln (1942); they derived the data from a survey of experiment station and college herds of eight States and the herds maintained by the United States Bureau of Animal Industry. The figure on weaning weight is calculated from their data on size and weight of litter. The age of weaning for the non-inbreds is 60 days whereas that of the crosses is 56 days. Lush and Molln (1942) give a figure on number born but it includes pigs born dead; hence it cannot be compared to the recorded number born alive in this study.

The figure on rate of gain is an average figure derived from a sample of 79

feeding experiments conducted by midwestern Experiment Stations. The average is not derived from *all* lots but only from the *best* performing lot in each experiment. This should constitute a satisfactory figure because in most feeding experiments, of the lot type, an attempt is made to have at least one lot that is fed as adequate a ration as possible.

TABLE 4. PERFORMANCE OF LINE CROSSES WITH SELECTED NON-INBREDS

	Ave. No. weaned	Weaning wt., lb.	Rate of gain, lb.	180 day wt., lb.
Outbreds	5.5	29	1.41	189
Crossed lines	6.76	36	1.53	238*
Crossed lines and breeds	6.23	41	1.62	254*

* Calculated by the formula 120(weight/(age−60)). Pigs were weighed out when they reached 200 pounds or were 180 days old.

The authors believe that all three of the above-mentioned checks should if anything constitute a handicap to the crossed lines because the non-inbreds were under the direct supervision of specialists in swine husbandry, whereas the crossed stock was under the supervision of men engaged in diversified activities. Two of the men supervise five classes of livestock and the other two supervise research on crops and have varied administrative activities as well as the work with livestock.

The figure on 180 day weight is taken from the Larrowe Milling Company's average growth chart and is used through the courtesy of the Larrowe Milling Company. It, however, is represented by them as only an *average* figure and is used as a basic figure in comparing the effects of various rations on the growth of swine.

In each of the four items of comparison the line crosses show an advantage.

Discussion

The data on the performance of line crosses both within and between breeds are encouraging as to the prospects of making practical use of inbred lines. The results do not substantiate Eaton's (1941) generalizations regarding the possible practical use of inbred lines of farm animals.

The results are even more encouraging when it is taken into account that the crosses, with but two exceptions, were made on pure line females. In addition, the breed crosses were all made to the parental stock that was low in fertility and in milk production. On the basis of results with breed crosses of non-inbred stock we can assume that crosses involving three or perhaps four lines (crossbred females will thereby be used) will show still further improvement.

A further point of encouragement is the fact that these data include all the crosses made. In the development of hybrid corn many of the lines producing the less desirable crosses are discarded. It can be assumed that further work will show that certain lines cross to better advantage, than others and that some now carried may be discarded.

These data are not sufficient to allow final conclusions but an examination of the data from the individual crosses indicates that the best performing crossbreds are more likely to be produced by the best performing inbred lines; in this respect the results are similar to those reported by Hayes and Johnson (1939) and Johnson and Hayes (1940) for corn. If that is correct then it is imperative that animal breeders develop inbred lines as superior in performance as possible.

Summary and Conclusions

A report is given on the accumulation of data on 13 lots of crosses between inbred strains of swine.

The evidence presented supports genetic theory and past experience with other species that increased vigor usually follows the crossing of inbred lines.

The degree of increased vigor was in close keeping with the decrease in the coefficient of inbreeding of the crossbreds.

Line crosses between breeds gave more increased vigor than line crosses within the Poland China breed. The amount of increased vigor resulting from line crosses between breeds rather than within a breed is in close keeping with the increased vigor resulting from the crossing of breeds of non-inbred swine in a previous experiment.

The genetic diversity of the parental stocks appears to be an important factor affecting the amount of increased vigor.

Superior lines appear to produce the superior crossbreds. There is nothing in these experiments to encourage the development of inferior inbred lines.

A comparison of the performance of the crossbreds within and between breeds, with that of selected well bred and well cared for non-inbreds lends encouragement to this method of improving swine.

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A COMPARISON OF THE EFFECTS OF INBREEDING AND SELECTION ON PERFORMANCE IN SWINE[1]

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THE generalization that *on the average* inbred animals are less vigorous than random-bred or outbred animals is amply supported by observation and experiment. However, the statement is common to most textbooks on animal breeding that a moderate amount of inbreeding can be successfully practiced in the production of purebred livestock if it is accompanied by judicious selection of breeding animals.

The founders of our pure breeds must have exercised considerable skill in selection since it is known that they used inbreeding to hasten purification and managed, at the same time, to improve the breeds. Students of animal breeding agree that inbreeding was used effectively in the formative stages of the development of existing breeds. In later days the average merit of all animals produced, as contrasted to the merit of only the best, apparently began to receive more weight in the evaluation of breeding practices. At any rate inbreeding passed from favor, and has continued to be avoided by most breeders of purebred livestock.

By about 1920 the science of genetics had developed sufficiently to explain why inbreeding tends to reduce vigor and that if it does *selected inbred lines should in crosses produce stocks more vigorous than random-bred animals* (Wright, 1922, 1922a). Shortly thereafter a number of attempts to produce inbred lines of swine by continuous full-sib matings were initiated (McPhee, Russell, and Zeller, 1931; Hughes, 1933; Hodgson, 1935). On the whole they met with indifferent success though the results of Hughes (1933) and Godbey and Starkey (1932) suggest that Berkshires may suffer less from inbreeding than other breeds involved. Looking back, it appears that the inbreeding was too rapid to allow its consequences to be greatly affected by selection (McPhee, 1936). At the same time selection was probably not as intensive as it might have been. One of the lines started by Hodgson at the Minnesota S. E. Experiment Station in 1922 (the M line) is still being maintained. While full-sib matings have not been practiced since 1937, the M line now has an average coefficient of inbreeding of 72 per cent. Its performance is somewhat less satisfactory than that of most purebred swine.

In the meantime corn breeders had produced highly inbred lines, demon-

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strated the validity of genetic theory, and begun to convince commercial corn producers of the value of hybrids. That they succeeded while livestock breeders were making little progress was partially due to the fact that larger numbers of lines could be started with comparable effort and expense thereby permitting more selection between lines.

One of the first attempts to develop an inbred line of swine using less intense inbreeding (half-sib matings) was made by Craft and reported in detail by Willham and Craft (1939). While some loss in merit was experienced the line has been successfully maintained. The U. S. Department of Agriculture started several lines of Chester Whites in 1922 that in 1936 averaged 35 percent inbreeding. Fertility was apparently somewhat reduced (Hetzer *et al.*, 1940). In 1930 Lush and Culbertson (1937) established a closed herd of Poland Chinas in which four boars were to be used each year. By 1937 the average coefficient of inbreeding was only 15.4 percent. This line is still being maintained and is performing satisfactorily. These results suggested that in the long run inbreeding less intense than full-sib matings might prove more efficient in the production of useful lines of inbred swine.

In 1937 the Regional Swine Breeding Laboratory was established in cooperation with the experiment stations of several Corn Belt States. The work of the Laboratory is summarized by Craft (1943). Its purpose was to study inbreeding in relation to the improvement of swine. An important problem was to determine how rapidly inbreeding can be advanced without serious loss of vigor when selection is maximum. Good performance in inbred lines is important even though their principal commercial use is to be in line crosses for the production of market hogs. Hayes and Johnson (1939) and Johnson and Hayes (1940) have shown that on the average the best-performing inbred lines of corn produce the best hybrids. Furthermore, the commercial value of cross-line hogs must compensate for the increased cost of production (over outbred breeding stock) of not only those inbreds actually used in crossing lines but of all inbreds raised.

Two reports have been published on inbred lines being developed in cooperation with the Regional Swine Breeding Laboratory. Baker and Reinmiller (1942) reported that in 4 lines of Durec Jerseys in which the average inbreeding went from 7 to 30 percent between 1937 and 1941 there was no significant loss in any element of merit measured and an actual increase in 180 day weight. Winters *et al.* (1943) reported that some lines in which inbreeding had been raised from zero in 1937 to around 30 percent in 1941 were at least equal and possibly superior in performance to the foundation animals.

It is the purpose of this paper to outline and evaluate the factors affecting the gain or loss of merit in inbred lines so far as possible from data gathered at Minnesota and the published results of other workers.

Procedure

The problem was considered only from the standpoint of selection based on performance of the individual animals. Extension of the results to include selection based both on the individual and its progeny or sibs depends on the relative value of the different methods of selection. The comparative effectiveness of different selection procedures has been considered by Dickerson and Hazel (1942) and Lush (1943).

When selection is based on individuality alone the expected change in merit per generation depends on

1. The amount by which the inbreeding is increased,
2. The average change in phenotypic merit that would result per unit increase in inbreeding in the absence of any selection,
3. The extent to which phenotypic differences within groups from which breeding animals are selected are heritable, and
4. The average amount by which the phenotypic merit of breeding animals excels the mean phenotypic merit of the group from which they were selected (this quantity is termed the *selection differential*).

Symbolically,

$$y = bI + sH \qquad (1)$$

where

y is the expected change in phenotypic merit per generation,
I, the increase in inbreeding per generation,
s, the selection differential,
H, the average increase in phenotypic merit of offspring per unit of s when $I = 0$,[3] and
b, the average change in phenotypic merit of offspring per unit of I when either s or $H = 0$.

bI is the change in phenotypic merit due to inbreeding; since b is change per unit of inbreeding and I the number of units by which inbreeding changes. sH is the change in phenotypic merit resulting from selection; since H is increase in merit of offspring per unit of s, the selection differential. Obviously the sum of the two equals the net change.

When there is neither an increase nor decrease in merit ($y = 0$), selection is just sufficient to offset the effect of inbreeding. Thus, by setting y equal to zero and solving for I, we obtain in terms of s, b, and H the maximum amount by which inbreeding can be increased per generation without change in merit,

[3] H, being dependent on the amount of heritable genetic variation, will decrease as inbreeding increases, since inbreeding reduces the genetic variation within lines. It can be assumed that H will decrease approximately in proportion to $(1 - F)$ where F is the average inbreeding coefficient of the parental generation.

$$I = \frac{-sH}{b} \qquad (2)$$

It remains to supply values of s, b and H for different elements of merit.

The selection differential (s) for a particular characteristic depends mainly on

1. The number of traits being considered in selection,
2. The amount of variation in each,
3. The relative emphasis placed on each,
4. The correlations among them, and
5. The proportion of available animals needed for breeding.

The selection differentials actually attained in inbred lines at Minnesota over a five-year period were calculated to serve as a guide to what they may average in practice. In selection during that time litter size, growth rate, and feed per 100 pounds gain (the latter was known only for litters, not for individuals) received primary emphasis; some consideration was given to body score (see Winters *et al.*, 1943). The values obtained are listed in table 1.

TABLE 1. SELECTION DIFFERENTIALS* ATTAINED IN POLAND CHINA LINES AT MINNESOTA

Sex	Litter size at birth (Pigs per litter)	Av. daily gain (lbs.)	Body score	Feed per 100 lbs. gain (lbs.)
Gilts	1.12	.107	2.7	−1.5
Boars**	1.12	.155	2.8	−0.7

* Selection differentials for litter size reported by Willham and Craft (1939) were 0.8 for dams of selected boars and 1.2 for dams of selected gilts. For daily gain from 60 to 180 days their selection differentials were .07 and .165 for females and males, respectively.

** The numbers of litters sired by each boar were used for weighting the values for individual boars when obtaining these averages.

The selection differentials for size of litter were obtained for each individual by comparing size of litter in which the animal was born with the mean for all gilt litters in the case of those out of gilts and with the mean of all other litters in the case of those out of sows over 16 months of age. They were then averaged. They actually represent the final stage of selection among the dams of the litters.

The selection differentials for average daily gain, body score, and feed cost represent the mean differences between the animals selected and the averages of the groups from which they were chosen. For feed cost the value observed for a litter was used for all individuals in the litter.

The values for body score are in arbitrary units and serve only to show

that the animals saved for breeding were considered, when scored, to be better than average in conformation.

The negative values for feed cost indicate that breeding animals came from litters requiring less than average amounts of feed. These low values reflect the fact that on the whole there was little variation in feed cost among litters. They would have been larger if there had been an opportunity to cull entire litters on that basis alone. In the case of litter size that was possible since more litters were farrowed than were fed out; entire litters were culled at weaning on the basis of number farrowed.

Intra-year, intra-line regressions[4] on inbreeding were used as estimates of *b*. The data used were on all the inbred lines raised at Minnesota (see Winters *et al.*, 1943) and included all collected through 1942. In the data on 337 litters the regression of average daily gain on inbreeding was $-.0027 \pm .0010$ lbs. Nordskog (1943) reported the regression as $-.0022$. Since these two studies involved practically equal amounts of data (a large portion was common to both), $-.0025$ will be used as the estimate of *b* in the remainder of the paper.

The regression of litter size on inbreeding was calculated for gilt litters only since sows saved for a second litter were highly selected on the basis of size of first litter. The regressions on inbreeding of dam and litter, respectively, were $-.020 \pm .016$ and $-.032 \pm .018$. The corresponding partial regressions were $-.009$ and $-.028$. Taken at face value they would indicate that for every one percent increase in the inbreeding of both dam and litter there would be a decrease on the average of .037 pigs per litter.

Estimates of H for litter size and daily gain were taken from the literature. Lush and Molln (1942) estimated repeatability of litter size in random-bred populations at .17. H cannot exceed repeatability but may be lower. They also reviewed literature on the correlation between dams and daughters for number farrowed which supported an estimate of about .17 for H.

Nordskog (1943) using two independent methods obtained estimates of .21 and .40 for H of daily gain. The latter figure was corrected to the basis of a random-bred population; the former was not. If it had, it would have been about .24. Lush (1936) estimated that H for daily gain was about .24. Baker *et al.* (1943), Hazel (1943) Whatley and Nelson (1942) and Whatley (1942) estimated H of 180 day weight as .25, .30, .23 and .30 to .40, respectively. H is probably somewhat higher for daily gain from weaning to 200

[4] These regressions would tend to underestimate *b* if

1. There were a tendency for the pigs with most rapid growth and/or from the largest litters to be used in the closest mating, or
2. The selection differentials were higher for the highly inbred pigs of a group than for those with less inbreeding. The latter would affect the regression only if there was an intra-year, intra-line correlation between the inbreeding of parents and offspring. This correlation was .45.

pounds than for 180 day weight (see Comstock *et al.*, 1942). It appears that .30 would be a safe figure for H of daily gain in random-bred populations.

Considering litter size which is expressed only in the female, $\frac{1}{2}s$ must be used in formula (2) instead of s. Using the values $s=1.12$, $b=-.037$, and $H=.17$, we obtain

$$I=\frac{-.56\times.17}{-.037}=2.57.$$

Considering daily gain and using $s=(.107+.155)/2=.13$, $b=-.0025$, and $H=.30$, we obtain

$$I=\frac{.13\times.30}{.0025}=15.6.$$

At face value these results indicate that inbreeding is much more likely to cause a decline in litter size than in growth rate. As the inbreeding of the parental generation (F) increases these values would be only $(1-F)$ times as large since H decreases in proportion to $(1-F)$ with increased inbreeding.

If formula (1) is divided by I, the units of change in inbreeding per generation, we have the average change in merit expected per unit of inbreeding,

$$y/I=b+\frac{sH}{I}. \tag{3}$$

Over a five-year period at Minnesota the average value of I in six lines has been about 8 or 9 (average increase in inbreeding of .08 – .09). Using (3) with H multiplied by the approximate average of $(1-F)$ for all years, we obtain for litter size

$$y/I=-.037+\frac{.56\times.17\times.90}{8}=-.026.$$

Doing the same for daily gain gives

$$y/I=-.0025+\frac{.13x\times.3x\times.85}{8}=.0017.$$

These represent the changes in litter size and daily gain expected per unit of inbreeding with the intensity of selection and rate of inbreeding as they have been in these lines at Minnesota. They were compared with the actual change as measured by the intra-line regressions of merit on inbreeding obtained from yearly means weighted by numbers of litters or individuals concerned. In the case of litter size the regression was based, as before, on

gilt litters only. The regressions were −.031 for litter size and .0052 for daily gain.[5] There is qualitative agreement between the theoretical and actual regressions; litter size decreased and daily gain increased. The increase in growth rate was greater than expected. However, some change in the ration fed was made during this period so it is impossible to state how close the agreement might otherwise have been, but it is considered doubtful that growth rate would have decreased instead of increasing.

Discussion

Unfortunately the values used for b may be considerably in error[6] particularly if applied to levels of inbreeding outside the range for the population on which they were estimated. Those for H are probably reasonably satisfactory. It is encouraging from the standpoint of accuracy, however, that the agreement between actual and theoretical results was fairly close. It is interesting to examine the results of other inbreeding experiments for concordance with these. The history of the early lines based on full-sib matings was one of difficulty with some phase of fertility. Decrease in daily gain was usually experienced but in no case was the loss of lines attributed to failure of the animals to grow. Hughes (1933) reported an increase in fertility but the numbers involved were small. Wright (1922) reported litter size suffered much more than growth rate in inbred guinea pigs. The results reported by Willham and Craft (1939) showed a progressive decline in litter size (somewhat greater than would be expected from the above) but if the results of the first generation were omitted it might be concluded that there was some increase in growth rate; certainly there is no evidence of a decline after the second generation. Hetzer, Lambert and Zeller (1940) reported a decline in litter size that was probably somewhat more rapid than that predicted from the results of this study. However, Baker and Reinmiller (1942) reported no significant change in litter size with increased inbreeding but an increase in 180 day weight.

It appears safe to conclude that difficulty in maintaining fertility is more likely to interfere with the development of inbred lines than declining

[5] These regressions were calculated from the same data as the intra-line, intra-year regressions used as estimates of b. However, they were calculated from the line means by years whereas those used to estimate b were calculated from the variation within lines and years; thus independent information was used to compute the two sets of regression coefficients and, therefore, these constitute a valid check on the expected changes in merit.

[6] Hetzer and Lambert (1940) reported an intra-year regression of litter size on inbreeding of litter much larger (−.25) than the one obtained in this study. However, that is obviously too high to represent the real average effect of inbreeding on litter size. In inbreeding up to 40 percent they appear to have lost about two pigs per litter. Assuming no selection (they claim only a little) this would represent a regression of about −.05.

Whatley reported an intra-line, intra-year regression for 180 day weight of −.76 lbs. If 20 percent of this were in preweaning gain it would correspond to about −.0048 for daily gain after weaning. However, the effect of age of dam was not removed in the calculation of this coefficient. Since pigs from older dams were heavier at 180 days, as is usual when other things are equal, and very likely averaged somewhat lower in inbreeding this coefficient may have overestimated the effect of inbreeding on growth rate.

growth rate. This is doubly significant since reduced fertility automatically reduces the amount of selection that can be practiced for both fertility and other characters. It appears that every effort should be directed towards maintaining fertility. In the lines studied gilts have been selected as rigidly as boars on the basis of size of their dam's litter. Since fewer boars than gilts are required it should be possible to select them from larger litters without compromising too much on other important qualities. At Minnesota pigs are handled as litters until they reach market weight and therefore limitations on numbers that can be handled are in terms of litters. However, it is possible to farrow more litters than can be raised after weaning. This is now being done. Since no more boars are required but larger litters are made available to select them from it should result on the average in making it possible to select boars from larger litters without sacrificing elsewhere. Possibly some attention should be given to sibs of the sires of litters in an effort to extend selection for litter size to sires as well as dams in lines where more than one sire is being used.

The most obvious means of maintaining any important characteristic is to avoid too intense inbreeding, but since the desired end is to produce highly inbred lines as rapidly as possible this should be resorted to only to the extent absolutely necessary. *b*, the effect of inbreeding, is not subject to human control except as one may be successful in securing foundation stock carrying few undesirable recessive genes. It is known that some animals perform better when inbred than others. The selection differentials can be increased by putting less emphasis on other characters. Attention to unimportant characteristics should be cut to a minimum.

H can be increased only by reducing sources of environmental variation to a minimum or by making corrections for sources of non-genetic variation that can be measured but cannot be held completely constant. It may be possible to accomplish something in these directions. All the factors contributing toward efficiency of performance are affected materially by influences other than genetic. Studies of Minnesota data (unpublished) have revealed that: (1) the age of gilt at first farrowing affects first litter size about $\frac{1}{3}$ live pig for one month's deviation from 12 months of age, (2) that pigs out of sows average about 4 pounds heavier than pigs out of gilts throughout the postweaning test period, and (3) that feed requirements increase with increased weight at weaning which is in keeping with results reported by Ashton and Crampton (1943); and Molln (1942) reported that score was affected by weight at time of scoring. In order, therefore, that selection be as effective as possible it is imperative that all records of performance be gathered under as uniform conditions as possible and where this is impracticable suitable correction factors be introduced.

Summary

Factors responsible for changes in merit of inbred lines have been identified and their net effect expressed symbolically. The rate at which inbreeding can proceed without loss of merit when selection is of the intensity practiced over a period of years in lines at Minnesota has been estimated for litter size and average daily gains. These estimates are subject to considerable error, but the theoretical and actual results were in reasonable agreement. It is concluded that litter size is much more difficult to maintain in lines being inbred than is growth rate, which is in agreement with the published results of other inbreeding experiments. Suggestions are advanced for making selection for fertility more effective. The results of this report emphasize the necessity for maximum attention to selection in the development of inbred lines of swine.

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HERITABILITY OF TYPE IN POLAND CHINA SWINE AS EVALUATED BY SCORING

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EVALUATION of the heritability of type in swine has practical importance to the extent that type is associated with productivity, rate and economy of gain and carcass quality, because it permits an estimate of the rate of change in swine type to be expected from selection. Relatively little is known of the relationships between type and economic characteristics of swine within herds, where variation in type is usually rather limited. However, there is general agreement that hogs ranging from the extremely small to the extremely large types may show rather striking differences in such characters as fertility, viability, rapidity and economy of gains, as well as in certain carcass characteristics. In studies with small-, intermediate- and large-type swine raised at the Beltsville Research Center, Beltsville, Md., Zeller and Hetzer (1944) found intermediate-type hogs to be superior, in general, to those of small and large types both from the standpoint of the producer and current market requirements. Phillips and Zeller (1943), studying the sexual development of small- and large-type swine, reported that full spermatogenic activity did not occur at so early an age in small-type boars as in large ones. Large-type sows were younger, on the average, at first estrus than small-type sows.

The purpose of the present investigation was to estimate the relative importance of heredity and environment in determining the type classification of the swine included in the studies mentioned above.

Materials and Methods

The data studied are the scores of 731 pigs representing 210 litters out of 106 sows and by 32 boars. The parent stock consisted of small-, intermediate- and large-type strains of Poland Chinas from unrelated sources, and two different crosses between strains. Of the 210 litters, 40 were from the small-type strain, 75 were from the intermediate-type strain, 78 were from the large-type strain, 12 were from the 6 possible crosses between strains, and 5 were out of sows obtained from 2 different crosses between strains. Thus there were 11 groups of pigs differing in the type strain of the sire or dam, or both. Seven of the boars and 5 of the sows had offspring in more than one

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group. Owing both to the frequency with which new breeding stock was introduced from without and attempts to avoid inbreeding, most of the animals were not inbred.

Data from 14 seasons are included, from the spring of 1931 through the spring of 1934 and from the spring of 1935 through the spring of 1938. Although not all pigs farrowed during the same season were fed and handled in exactly the same manner, the different treatments were all reasonably good and the average scores differed little between treatments. Accordingly, corrections for treatment differences within seasons were not thought necessary.

Type was evaluated by two or three judges when the pigs were removed from the feed-lot. All pigs fed during the first 10 seasons were scored at approximately 225 pounds, while during the last 4 seasons all pigs were scored at the same degree of finish as judged by visual inspection. The small-type strain consisted largely of short-bodied, low-set animals capable of being fattened at an early age though slow in reaching sexual maturity. Intermediate-type hogs tended towards more length of body and legs and were not so well finished at as early an age as the former. Pigs of the large-type strain tended to be still longer in both body and legs, though not so rangy in type as some Poland Chinas. In general, they were somewhat narrower and more shallow than either of the other strains. Based on the variability in type observed between as well as within these three strains, the scores adopted ranged from 1 to 9 and the score card was arranged so as to have differences in scores be as nearly proportional to differences in type as visual inspection by experienced judges permitted. Notwithstanding close adherence to this plan, it is conceivable that a part of the differences in scores between type strains may have resulted from the judges having an unconscious psychological bias in favor of certain scores, because of their knowledge of the type strain of each pig at scoring time. However it is unlikely that the strain differences in the scores given were appreciably larger than they would have been if each pig had been unidentified as to strain when scored, for as figure 1 shows, there was some overlapping in type scores between strains.

Results

Analysis of variance as described by Snedecor (1940) was used to determine the relative importance of differences (1) between seasons within strains, (2) between the large-, intermediate-, and small-type strains within seasons, (3) between sire progenies within the same strain and season, (4) between litters by the same sire within the same strain and season, and (5) between litter mates. An estimate of the variance associated with each of these five groups of causes is obtained from table 1. Included in table 1 is a comparison

of differences, (1) between full-sib litters with those (2) between sire progenies that are maternal half-sibs. This comparison provides a second estimate of the variance arising from sire differences within strain. Also, comparison of differences between full-sib litters with those between litter mates permits an estimate of the environmental variance between full-sib litters (from seasonal variation plus changes in environment provided by the same sow to different litters).

In testing for the statistical significance of each source of variation, it is

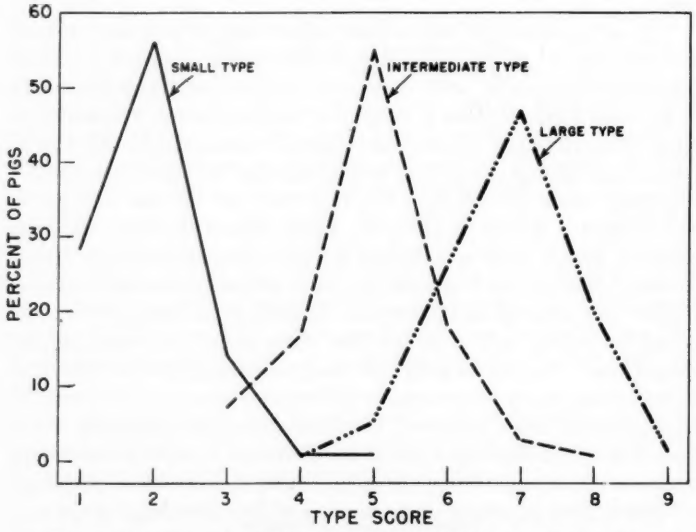

Figure 1. Frequency distributions of type scores for pigs from small-, intermediate-, and large-type strains.

apparent from their composition that only the mean squares between litters by the same sire and between full-sib litters may properly be compared with the intra-litter mean square. On this basis, litter differences within sire, season and strain were highly significant but the environmental differences between full-sib litters were not. Differences between sire progenies within strain and season fell just short of the 5 percent level of significance when compared with differences between litters by the same sire. Similarly, the sire differences between maternal half-sib progenies were not quite significant compared with differences between full-sib litters. Intra-season differences between the three type strains were very large and highly significant

TABLE 1. ANALYSIS OF VARIANCE FOR EVALUATING DIFFERENT CAUSES OF VARIATION IN PIGS' SCORES

Source of variation	Degrees of freedom	Mean square	Composition of mean square*		
Between seasons within strains	34	2.129	$A+\bar{d}L+\bar{d}_1(D-L)+\bar{s}_1S_1+\bar{y}Y$	$\bar{d}=4.055$ $\bar{s}_1=10.695$	$\bar{d}_1=3.934$ $\bar{y}=17.714$
Between S, I and L type strains within seasons	23	86.346**	$A+\bar{d}D+\bar{s}S_1+\bar{t}T$	$\bar{d}=3.995$ $\bar{s}=12.099$	$\bar{t}=16.762$
Between sire progenies within strain and season	26	1.317	$A+\bar{d}D+\bar{s}S_1$	$\bar{d}=3.343$ $\bar{s}=7.515$	
Between litters within sire, strain and season	136	0.867**	$A+\bar{d}D$	$\bar{d}=3.347$	
Within litters	521	0.530	A		
Within season and strain	683	0.627	$A+\frac{162}{683}\bar{d}D+\frac{26}{683}\bar{s}S_1$		
Between sire progenies within dam and strain	50	1.004	$A+\bar{d}(Y+L)+\bar{s}S_1$	$\bar{d}=3.430$	$\bar{s}=4.163$
Between full-sib litters	49	0.685	$A+\bar{d}(Y+L)$	$\bar{d}=3.140$	
Between litters from same dam and strain	99	0.846	$A+\bar{d}(Y+L)+\frac{50}{99}\bar{s}S_1$	$\bar{d}=3.286$	$\bar{s}=4.163$

* Based on mathematical analysis worked out by Dickerson.

The number of times each component of variance (D, S, T, or Y) is represented in a mean square between subclasses within groups can be calculated from the following general formula.

$$\bar{k}=\frac{\Sigma\left(\frac{\Sigma k^2}{\Sigma k}\right)_c-\Sigma\left(\frac{\Sigma k^2}{\Sigma k}\right)_g}{N_c-N_g}$$

Where: k = number of observations in a set which have identical variance from the source concerned (e.g. number in a sire progeny, for the variance from sire differences),

N_g = number of groups with 2 or more subclasses each (e.g. strain-season groups composed of 2 or more sire progenies)

N_c = total number of subclasses in N_g groups.

When there is a single basis of classification, the general formula simplifies to:

$$\bar{k}=\frac{N-\frac{\Sigma k^2}{N}}{N_c-1}$$

which has been given previously by Winsor and Clarke (1940, p. 27) and by Lush and Molln (1942, p. 12).

The general formula for $\bar{k}$ holds even when some sets are included in more than one subclass. In the present analysis, for example, 19 of the 32 sires and 56 of the 106 dams had progeny in more than one season. To obtain the correct coefficients for the sire variance (S) and for that part of the litter variance (D) which is the same for all litters of a given dam (D−L), in the mean square *between seasons within strains*, it is only necessary to use the total number of progeny in all seasons for a sire (s_1) or a dam (d_1) in the second term of the numerator, instead of the number of progeny in a single season (s and d). Thus,

$$\bar{d}_1=\frac{\Sigma\left(\frac{\Sigma d^2}{\Sigma d}\right)_{ty}-\Sigma\left(\frac{\Sigma d_1^2}{\Sigma d_1}\right)_t}{N_{ty}-N_t} \quad \text{and} \quad \bar{s}_1=\frac{\Sigma\left(\frac{\Sigma s^2}{\Sigma s}\right)_{ty}-\Sigma\left(\frac{\Sigma s_1^2}{\Sigma s_1}\right)_t}{N_{ty}-N_t},$$

compared with the differences between sire progenies of the same strain and season. Differences between seasons within strains, however, were not enough larger than the differences between sire progenies within strain and season to have statistical significance. The fact that differences between full-sib litters were not significantly larger than those among litter mates also indicates that the seasonal variation in scores was not great.

The estimates of variance from each source are obtained from table 1, as follows:

$$A = 0.530 = \text{intra-litter variance}$$

$$D = \frac{0.867 - 0.530}{3.347} = 0.1007 = \text{litter variance within season, strain and sire}$$

$$S_1 = \frac{1.317 - 0.867}{7.515} = 0.0599 = \text{sire variance within season and strain}$$

$$S_2 = \frac{1.004 - 0.699}{4.163} = 0.0732 = \text{sire variance between seasons within strain}$$

$$S = \frac{0.0599 + 0.0732}{2} = 0.0666 = \text{average estimate of sire variance within strain}$$

$$T = \frac{86.346 - 1.738}{16.762} = 5.048 = \text{strain variance (i.e. between small-, intermediate and large-type strains, omitting crosses)}$$

$$Y + L = \frac{0.685 - 0.530}{3.140} = 0.0494 = \text{environmental variance between full-sib litters}$$

$$Y = \frac{2.129 - .530 - 3.534(.1007) - 10.695(.0666) - (4.055 - 3.534)(.0494)}{17.714 - (4.055 - 3.534)}$$

$$= 0.0294 = \text{seasonal variance}$$

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where N_{ty} is the number of strain-season subclasses and N_t the number of strains. Each litter of a sow provides an independent sample of the variance from temporary litter environment (L). Hence, the coefficient for L is calculated as though each dam had only one litter, i.e.

$$\bar{d} = \frac{\Sigma\left(\frac{\Sigma d^2}{\Sigma d}\right)_{ty} - \Sigma\left(\frac{\Sigma d^2}{\Sigma d}\right)_t}{N_{ty} - N_t}$$

** Signifies probability of chance occurrence <.01.

These estimates of the variance from each source are interpreted as follows:

$A = 0.530$ = variance between two pigs from the same litter.

$A+D = 0.631$ = variance between two pigs from different sows, but from the same sire, strain and season.

$A+D+S = 0.697$ = variance between two pigs differing in both sire and dam but from the same strain and season.

$A+D+S+T = 5.745$ = variance between two pigs from different type-strains born in the same season.

$A+D+S+T+Y = 5.775$ = variance between two pigs from different type strains and born in different seasons.

$A+Y+L = 0.579$ = variance between two pigs from the same sire and dam, but born in different seasons.

The purpose of this analysis of type scores is to estimate the relative importance of variance from the following genetic and environmental sources.

G = total variance from differences in transmitting ability among individuals from the same strain and season,

M = variance from differences in environment which is the same for all litters of the same dam (i.e. permanent sow influence),

L = variance from differences in environment which is the same for litter mates but varies between litters of the same sow (i.e. temporary litter environment),

E = variance from intra-litter differences in environment, from discrepancies between phenotype and transmitting ability caused by gene interactions, and from inaccuracies in the scoring technique,

T = variance from differences between the small-, intermediate-, and large-type strains,

Y = variance from seasonal differences in environment which affect all pigs born in the same season alike.

Since mating was essentially random within each strain, the variance from each source would be constituted about as follows (Dickerson, 1942): $A = \frac{G}{2} + E$, $D = \frac{G}{4} + M + L$ and $S = \frac{G}{4}$. Therefore, it is evident that the fraction of the variance within strain and season accounted for by heritable differences in the pigs can be estimated as: $\frac{G}{A+D+S} = \frac{4S}{A+D+S} = .382$ or

38 percent.[2] Non-heritable differences among litter mates accounted for $\frac{E}{A+D+S}=\frac{A-2S}{A+D+S}=.569$ or 57 percent, while temporary and permanent differences in litter environment together caused only $\frac{M+L}{A+D+S}=\frac{D-S}{A+D+S}=.049$ or 5 percent of the variance within season and strain. Differences in temporary litter environment (L) were large enough to make the environmental variance between full-sub litters (Y+L = .0494) nearly twice the seasonal variance (Y = .0294) and accounted for $\frac{L}{A+D+S}=.029$ or 3percent of the variance. Thus only about 2 percent of the variance appears to have been due to permanent differences in sow influence (M).

The heritable fraction of the intra-season variance between pigs in different strains can be estimated as:

$$\frac{G+T}{A+D+S+T}=\frac{4S+T}{A+D+S+T}=.925 \text{ or } 92 \text{ percent.}$$

Seasonal differences in environment had little influence on the scores, accounting for $\frac{Y}{A+D+S+Y}=.040$ or 4 percent of the variance between pigs differing in sire, dam and season and for $\frac{Y}{A+D+S+T+Y}=.005$ or one-half of 1 percent of the variance between pigs differing in season and strain.

Although no studies bearing on the same problem were found in the literature, Stonaker and Lush (1942) using a scoring scheme similar to the one used in this study, estimated that 20 percent of the variance within line and season in conformation of swine at 225 pounds was due to differences in the additive effects of their genes.

Discussion

The general conclusion indicated by the findings of this study is that differences in type such as generally exist between small-, intermediate-, and large-type herds of swine are due largely to differences in their heredity. This

[2] The difference between this estimate and the one given by Hetzer and Zeller on page 375 of the November 1943 issue of the JOUR. AN. SCI. is due largely to the fact that the latter was based on only one estimate of the sire variance, whereas the above value is based on the average of two estimates.

conclusion is supported by the fact that the hereditary variance in type scores based on differences between as well as within type strains was very high, being about 92 percent in these data, as compared to 38 percent within type strains. This conclusion is further substantiated by the experience of swine breeders with respect to the response of type to selection. This estimate undoutedly is somewhat above the true value for a breed as a whole, since all pigs used here were raised under the same management, and two of the three strains were deliberately selected as extremes in type. Aside from the effects of any errors in the scoring technique which might also have caused this estimate to be somewhat above the true value, this tends to increase the hereditary portion of the variance as compared to that typical of the general population of pigs subjected to varying herd management practices. However, the small seasonal variation found in the type scores suggests that environmental differences between herds do not greatly influence herd differences in type. Thus it appears certain that the genetic fraction of the variance would be larger in a population made up of different herds ranging from one extreme to the other in type, as in a whole breed, than within individual herds.

The estimate of heritability among pigs from the same type strain indicates the rate of progress to be expected by selection within individual herds where type is much less variable than in the breed as a whole. Thus if 38 percent is approximately the heritability within such herds, the most probable change in type in the next generation would be about 38 percent of the deviation of the animals selected as parents from the average of their generation. For example, if the animals selected as parents of each succeeding generation scored 1.2 points higher than the average, the average score of the population would be expected to shift in the same direction by about 0.46 of a point per generation.

If a breeder has access to stock from any herd in the breed, progress from selection toward either extreme should be faster than if he could choose only from his own herd, or other herds of the same general type, because the heritability estimate for the breed as a whole, about 92 percent, would apply to selection practiced on this basis. However, this faster rate of progress would diminish with each generation, since he would gradually find that no other breeder had animals more extreme in the desired direction than his own stock. Accordingly, progress would soon approach that expected within type strains and the lower heritability, 38 percent, would again apply. While continued selection in one direction could result in a type more extreme than the largest or the smallest to be found in the breed at present, there would be no point in breeding for a type more extreme than is compatible with economical swine production. Since both small- and large-type herds may still be

found, progress toward either extreme would be more rapid for a few generations if new breeding animals were brought in from herds representing the desired extreme than if all animals were replaced from within a breeder's own herd.

Summary

Data on 731 Poland China pigs were analyzed to determine the relative importance of heredity and environment in determining type as measured by a scoring scheme used at the Beltsville Research Center.

The intra-season variance in progeny scores due to differences between sires of the same type strain gave an estimate of 38 percent for the heritable part of the variance between pigs from different parents of the same strain. Because of the marked differences in scores between the small-, intermediate-, and large-type strains, the heritable portion of the intra-season variance between pigs in different strains was considerably higher, 92 percent.

Differences in litter environment accounted for 5 percent and differences in environment peculiar to the individual for 57 percent of the intra-season variance in scores among pigs of the same type strain. Seasonal variation in environment was responsible for only 4 percent of the total variance among pigs of the same type strain.

The heritability of type is apparently high enough for selection to be effective in changing the type of swine rather rapidly within individual herds. However, shifts in swine type can usually be made more rapidly by selecting breeding animals from herds in which type is more extreme in the desired direction than in a breeder's own herd. These conclusions are in harmony with the fact that in livestock history breeders have accomplished large changes in swine type rather quickly by selection for extremes in type.

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A STUDY OF THE PREDICTIVE VALUE OF SCORES ON BODY CONFORMATION OF PIGS TAKEN PREVIOUS TO FINAL SCORE[1]

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THERE is a distinct commercial advantage in being able to select breeding stock at an early age and this is even more important in a research program attempting to develop superior inbred lines.

Satisfactory performance in swine comprises five fundamental factors, namely: fertility, survival, rate of gain, economy of gain, and body conformation. Although it has been suggested that at times the importance of body conformation received more than its share of attention, it is one of the fundamental factors in the performance of meat animals.

In commercial swine production, animals are commonly marketed at weights from 200 to 250 pounds. The gilts to be used for breeding the next year's crop are usually selected shortly before putting the final finish on the market hogs when the gilts weigh about 190–200 pounds. The new herd boar is also usually selected at about the same weight. In purebred herds the situation is generally reversed and the least desirable individuals are culled from the prospective breeding stock. The breeding animals normally are selected when they approximate the weight at which the bulk of the hog crop is marketed.

Of the five fundamental factors affecting economy of swine production, fertility and survival, as judged by the performance of the litter, are appraised early in the life of the pig. (The greater percentage of deaths among growing pigs occurs previous to weaning and most of those that do occur after weaning are due to infectious diseases or accidents.)

Nordskog (1943) made an attempt to forecast rate of gain on the basis of various characteristics of the blood. Highly significant relationships were obtained between various constituents of blood and the growth that had taken place but their predictive values were very low.

Studies have been made of the reliability of rates of gain taken at different periods of pigs' growth. In data studied by Baker, Hazel, and Reinmiller (1943) the highest percent of the variance in weight attributed to heredity occurred at 112 days. Nordskog, Comstock, and Winters (1944) found, however, that the estimates of heritability of gains increased progressively by age until the pigs were 168 days old, at which age the study was terminated.

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The Problem

The type of body form deemed most desirable at market maturity was considered as a base, and the problem then was whether selection for body form could be made at an earlier age and remain reasonably effective?

Source of Data

The data were collected on the 1941 spring pigs from the herds maintained by the Minnesota Agricultural Experiment Station for its breeding project. At that time every animal was scored at the completion of the feeding period (200 pounds or 180 days of age, whichever was reached first) for (1) vigor, health, and thrift, (2) quality, (3) length of body, (4) conformation, (5) animal as a whole, and (6) grade. Each item received equal weight and the sum of these scores was taken as the final appraisal of the animal's body form.

For this experiment 417 gilts were scored at 112 days, but given only one score summarizing the above-mentioned details, which was compared later with the total scores taken at completion of the trial.

A total of 124 boars were scored in more detail than the gilts at 112 days, 140 days, and at completion of the trial (200 pounds or 180 days). The detailed scores were slightly different from those mentioned above which were standard for the Regional Swine Breeding Laboratory; they were (1) animal as a whole, (2) body length, (3) body depth, (4) ham, (5) quality, and (6) feet and legs. Each item received equal weight in scoring and they were summed for total score.

The data were gathered from five different herds, and the head herdsman of each herd was delegated to do the scoring. The herdsmen were well qualified for this work. The senior author had scored pigs with each of the men and was satisfied that they had essentially the same standards of perfection. This does not preclude the view that there were no differences in their scoring, for Fenske (1939) found that five men differed significantly in measuring body length of pigs with either a measuring stick or a tape, and also that there was considerable variance in repeated measurements taken by the same man on the same pigs. Since score is a qualitative rather than a quantitative measure, naturally some differences would result from the scoring by five individuals. Nevertheless, such scoring might give a better composite picture than had it all been done by one individual.

Data and Discussion

The correlations between scores at 112 days and at completion of the trial on the gilts is given by Stations and for the whole in table 1. The correlations are all sufficiently high so that they are significant at the 1 percent level. All

of the correlations excepting the one at Station No. 5 had a considerable margin beyond the 1 percent level; hence there can be no doubt regarding the high relationship between the two groups of scores. The prediction indexes[2] are, however, rather low.

TABLE 1. CORRELATION BETWEEN SCORE AT 112 DAYS AND FINAL SCORE FOR GILTS

Station	N	r	P.I.[1]
1	74	.62**	.22
2	52	.77**	.36
3	55	.50**	.13
4	138	.69**	.28
5	98	.30**	.05
Total	417	.60**	.20

[1] Prediction index (P.I.), calculated according to Treloar (1939), p. 126.
** Statistically significant at the 0.01 level.

In the selection of breeding animals, selections are always based on individuals and the breeder is, therefore, interested in the reliability of his individual selections. Since the correlation coefficient measures the degree of association between two things, the P. I. measures the predictive value of a correlation coefficient. The prediction index tends to emphasize the fact that correlations may be seemingly high and statistically highly significant and yet be relatively low in value for predictive purposes. Use of P. I. along with the correlation coefficient gives the breeder a much clearer picture of his ability to select.

Examination of the correlation coefficients given in table 1 indicates that a satisfactory job of selection could be done under certain conditions. If these correlations were on similar data for groups of 50 breeding cows or ewes, where only about 20 percent were culled each year, serious mistakes in selection would not be likely if based on correlations of the magnitude indicated. It is unlikely that the best animals would be culled, but some of the poorest animals probably would be retained. These mistakes would not be as serious as would the elimination of animals from the upper 20 percent but they would have an effect on the herd average.

In the selection of one, two, or three sires from a group of 40 prospects the

[2] The prediction index, P. I., may be used as an index of the predictive value of a correlation coefficient as it is a method of expressing the proportion of the total variation which is accounted for by the association of the two variables under consideration. In this it is similar to r^2 but the P. I. is expressed in terms of standard deviation whereas r^2 is related to the squared standard deviation. Although r^2 measures the proportion of variation due to the association of the two variables, it is not useful for predictive purposes. The P. I. is a complement to unity of the coefficient of alienation and both C. A. and P. I. are functions of r alone. An example of the relationships of the terms discussed is as follows: If $r=0.62$, $r^2=0.3844$: C. A. $=\sqrt{1-r^2}=\sqrt{0.6156}=0.7846$; P. I. $=1-$C. A. $=0.2154$ or 22 as given in table 1.

situation is different. Here the breeder is interested in selecting the best that is offered. A comparable situation prevails in the selection of females in a small inbred line of swine. At Minnesota an attempt is made to farrow a minimum of 10 litters in each line but at times only four are farrowed. When that happens, it is very important that each female farrowing pigs be not only above the average of the group from which she was selected but as close to the top as possible. In the selection of a herd sire or in the selection of a few females the individual becomes very important and improper selection is serious.

It will be noted that there are distinct station differences in the size of the correlations. A possible explanation is that various individuals did the scoring, but a more logical explanation is that the disagreement is due primarily to the way the different groups of pigs grew to market maturity. Hammond (1932, 1940) has called attention to the fact that an animal changes proportions as it grows and that different strains or breeds change proportions at different rates. Winters *et al.* (1942) and Comstock and Winters (1944) have called attention to the same point and verified it statistically by the use of body measurements taken at regular intervals. They have suggested that since swine approach market maturity by different paths of development, swine improvement measured in terms of economically important characteristics would be more rapid if conformation were considered only at market weight.

This suggests an additional weakness in early selection. If different lines reach maturity by unlike patterns of growth, it at least suggests that dissimilar genes for growth are present in the lines. In looking forward to ultimately possessing lines that will cross to give the most hybrid vigor, it is essential that the lines possess maximum gene differences. It would appear that if selection was effective in changing type, then early selection would lead all lines closer to the type of pig wherein the correlation was highest between early and final selection (Station 2). As it happens the authors consider the hogs at Station 2 to be the poorest representatives (in our project) of what is wanted in a modern market hog and that those at Station 5 are the best representatives of a modern market hog.

The correlations between the scores taken on the same characteristic of the boars at different ages are presented in table 2. The correlations are not all statistically significant but most of them are significant at the 1 per cent level. Of the six characters scored, ham showed the most consistent relationship from period to period. The correlations between total scores are remarkably consistent in that the correlations between scores at 112 and 140 days and between 140 days and final score are essentially the same and the one between 112 days and final score is only half as great as each of the others. It

would appear that the scores given on each characteristic were affected by the development of other characteristics. If this was the case then one error would tend to balance another and the net result would be for total score to give the most consistent correlations.

TABLE 2. CORRELATIONS BETWEEN SCORES OF BODY PARTS AT DIFFERENT AGES—112 DAYS (x), 140 DAYS (y), and FINAL SCORE (z)*

Body part	No.	$\sqrt{xy}$	P.I.	$\sqrt{xz}$	P.I.	$\sqrt{yz}$	P.I.
Animal as whole	124	.46**	.11	.21*	.02	.36**	.07
Body length	124	.36**	.07	.14	.01	0	0
Body depth	124	.50**	.13	.14	.01	.28**	.04
Ham	124	.56**	.17	.44**	.10	.45**	.11
Quality	124	.30**	.05	.0'	0	0	0
Feet and legs	124	.24**	.03	.23**	.03	.62**	.22
Total score	124	.56**	.17	.25**	.03	.52**	.15

* Statistically significant at the 0.05 level.
** Statistically significant at the 0.01 level.

It was somewhat surprising to find the correlations lowest between scores for quality. A possible explanation may be that the degree of condition makes considerable difference in the apparent quality an animal possesses, for during this period of growth pigs change and differ greatly in degree of condition.

The correlations between scores for body length were also low and the explanation for this likely lies in the suggestion made by Winters *et al.* (1942) that "It appears that differences tend to accentuate one another." Here as in the correlations on scores of females the prediction indexes are low.

In boars even more than with females the breeder is interested in individuals. A mistake made in the selection of one sire is enough to upset many years of constructive work. If we assume that we know what we want in the bodily form of boars at approximately 200 pounds, these results are not very encouraging in regard to the possibility of making exacting selections at an earlier age. Over one-half of the prediction indexes in table 2 are essentially zero. The rest indicate that the correlations are of little use for predictive purposes. The highest correlation of 0.62 between the 140 day and final score for "feet and legs" indicates that there is only about one chance in five of making proper selections at even as late an age as 140 days. These correlations further emphasize the problems of early selection of boars and the need for refinements in the technics of selection. It is desirable to castrate unwanted boars as early as possible but the breeder as yet has few yardsticks for the early, accurate selection of boars. In this connection it is also well to take into account that Stonaker and Lush (1942) estimated the heritability of score on pigs at market maturity as being only 20 percent.

The relationships between scores given at the same age for ham, length of body, and depth of body were studied through correlations which are presented in table 3.

TABLE 3. CORRELATIONS BETWEEN FULLNESS OF HAM (x), LENGTH OF BODY (y), AND DEPTH OF BODY (z) AT DIFFERENT AGES

Age	No.	$\sqrt{xy}$	P.I.	$\sqrt{yz}$	P.I.	$\sqrt{xz}$	P.I.
112 days	124	.42**	.09	.64**	.23	.64**	.23
140 days	124	.47**	.12	.42**	.09	.65**	.24
Final score	124	.39**	.08	.51**	.14	.64**	.23

** Statistically significant at the 0.01 level.

The correlations are all relatively high and they are all statistically significant at the 1 percent level. There is, therefore, a relationship between them. Here too the values of the predictive indexes are low. On this basis the prediction of score for length of body from the score on ham is likely to be rather poor.

Summary and Conclusions

A total of 417 gilts were scored when 112 days old and when taken off feeding trial (200 pounds in weight or 180 days old, which ever came first). A total of 124 boars were scored for six characteristics when 112 and 140 days old and on completion of the feeding trial.

Correlations were made between the scores on the same animals taken at different ages. Most of the correlations were sufficiently high to be statistically significant at the 1 percent level. The predictive values were, however, low, so low as not to be at all encouraging regarding the reliability of individual selection at an age far removed from the age at which it is known what type of form is desired.

The data suggest that different strains approach market maturity by different routes, i.e., that animals change body proportions at different levels of timing.

The correlations between scores for ham, length of body, and depth of body on boars were relatively high and statistically significant at the 1 percent level, yet the predictive value in each instance is rather low.

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CONGENITAL MALFORMATIONS, SYNDACTYLISM, TALIPES, AND PARALYSIS AGITANS OF NUTRITIONAL ORIGIN IN SWINE

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Introduction

THE object of this investigation was to study the physiological effect of certain rations on the sow through the reproductive and lactation periods.

Experiments conducted by Evvard (1913), beginning in 1910, were among the first to demonstrate that young sows fed only on corn and salt during the gestation period were unable to produce strong pigs. Snyder (1917), Hart and Steenbock (1919), Grimes (1921), the Arkansas Experiment Station (Martin, 1927), Morrison, Fargo, and Bohstedt (1928), Martin (1929), and others found that a ration of corn alone fed pregnant sows was not adequate to support reproduction and lactation. Aubel, Hughes, and Lienhardt (1929) demonstrated some beneficial effect from feeding 10 percent wheat germ meal to sows receiving a ration of yellow corn, alfalfa leaf meal, tankage, and steamed bone meal. The Michigan Station (Gardner, 1932) found that alfalfa leaf meal added to a ration of corn, barley, and oats gave satisfactory results during the gestation period of gilts.

Complete lactation records were not published with much of the work reviewed. Fishwick (1932) first reported abnormalities in pigs whose dams were fed practical swine rations. Hogan (1932) fed commonly used feedstuffs to sow pigs, weighing 50 to 100 pounds, in pens with wood or concrete floors. Their litters were not thrifty in appearance when weaned, and the weaning weights were subnormal. Hogan and Johnson (1933) reported that several years of experimentation had demonstrated that a ration of corn, tankage, linseed meal, cod liver oil, and a mineral mixture could be improved by including wheat bran or wheat shorts. The same authors in 1935, feeding essentially the same ration referred to above, found that sows produced pigs normal at birth and for a few days afterwards, but that soon began to die, the deaths continuing until weaning time. These investigations showed that a defective ration may cause a sow to secrete defective milk. Hogan, Johnson, and Gahley (1938) feeding a ration similar to the one used in the investigations reported above, described abnormalities of suckling

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pigs. Hogan and Johnson (1940), reporting further on the use of concentrates commonly used in swine feeding, found that the mortality rate among the pigs was highest in the first week. Almost 90 percent of all mortalities occurred in the first four weeks. These abnormalities included skin lesions, muscular incoordination and weakness, diarrhea, and collapse. Post-mortem examination revealed fatty liver, fatty kidneys, and hemorrhagic areas. Hogan and McRoberts (1940), found that supplementing the same basal ration with certain vitamins decreased the number of mortalities and increased the weaning weight of the pigs.

Experimental

These experiments were designed to study the effect of a ration composed of yellow corn, expeller soybean oil meal, calcium carbonate, and common salt with varied levels of alfalfa meal and/or other supplements upon the reproductive and lactation performance of the sow.

Young Chester White, Yorkshire, and Poland China sow pigs, evenly allotted and weighing about 55 pounds on the average, were placed in pens with concrete floors and concrete outdoor runs. The basal ration and the basal ration plus 10 percent alfalfa used in these trials is shown in table 1.

TABLE 1. RATIONS FED.

Feeds	Fed up to 100 lbs. live wt.		Fed after pigs reached 100 lbs. live wt.	
	Basal ration	Basal ration plus 10% alfalfa meal	Basal ration	Basal ration plus 10% alfalfa meal
Yellow corn	76.35%	68.34%	82.85%	75.34%
Expeller soybean oil meal	17.50%	16.00%	11.00%	9.00%
Alfalfa meal	5.00%	15.00%	5.00%	15.00%
Calcium carbonate	0.65%	0.16%	0.65%	0.16%
Common iodized salt	0.50%	0.50%	0.50%	0.50%
Total	100.00%	100.00%	100.00%	100.00%

The soybean oil meal was adjusted in the lot receiving the basal ration plus 10 percent alfalfa meal to make the total digestible protein of the two rations comparable. The calcium carbonate of the basal ration plus 10 percent alfalfa meal was decreased to compensate for the amount of calcium carried by the added alfalfa. The calcium phosphorus ratio was approximately 1.25:1 for each lot. The above rations with a nutritive ratio of 1:5.2 were fed until the pigs averaged 100 pounds in weight. After reaching this weight the protein level of the rations was reduced to give a nutritive ratio of 1:6.4.

The pigs were fed ad libitum until they reached the average weight of 200 pounds.

On the first trial four sows were selected from each lot to be carried through gestation and lactation. They were continued on the same ration they had received during the latter part of the growing period.

The sows were bred at approximately 8 months of age. Care was taken to feed the sows well enough to keep them in good thrifty condition without becoming too fat. During most of the period after they had passed the 200

TABLE 2. EFFECT OF RATION ON REPRODUCTION IN SWINE.

	No. of sows	Av. no. pigs farrowed	Av. birth weight	Av. no. pigs weaned per sow	Av. wt. at 56 da. of age
TRIAL 1			lbs.		lbs.
Basal ration (1)	3	11.3	2.78	4.3	18.4
Basal ration+10% alfalfa meal	4	11.0	2.72	8.25	24.6
TRIAL 2					
Basal ration (2)	4	10.2	2.40	2.0	20.1
Basal+para-aminobenzoic acid*	2	6.5	3.05	1.5	15.3
Basal+inositol*	1	15.0	2.29	4.0	16.5
Basal+para-aminobenzoic acid+inositol*	2	10.0	2.43	2.5	28.0
Basal+1% soybean lecithin*	1	8.0	2.41	6.0	12.5
Basal+10% alfalfa meal (3)	5	10.4	2.30	2.2	18.4
Basal+10% alfalfa meal+5% tankage*	1	2.0	2.40	0	0
Basal+10% alfalfa meal+para-aminobenzoic acid+inositol*	1	8.0	2.72	7.0	15.3
Basal+5% bran+5% middlings (4)	3	11.0	2.31	1.0	9.0
Basal+5% bran+5% middlings+5% fish meal*	1	11.0	2.69	0	0
Basal+5% bran+5% middlings+10% molasses*	1	4.0	2.05	0	0
Basal+5% bran+5% middlings+5% dried brewers' yeast*	1	10.0	2.37	0	0

(1) One sow sterile; (2) two sows sterile; (3) three sows sterile; (4) four sows sterile.

* Supplements such as para-aminobenzoic acid, inositol, soybean lecithin, tankage, fish meal, molasses and dried brewers' yeast, were added 10 days before parturition and continued for 20 days after farrowing. Para-aminobenzoic acid was fed at the rate of 4.5 grams per sow per day. Inositol was fed at the rate of 10 grams per sow per day.

pound mark, they were hand-fed to restrict their feed intake. Difficulty in obtaining conceptions was encountered in some sows of both lots, and this necessitated several services for certain of them.

The sows were allowed to farrow in quarters that had been thoroughly cleaned. In order to prevent anemia clean soil was placed in a corner of each pen, easily accessible to the young pigs.

To make the litters comparable, the number was reduced to 8 pigs each, with the exception of one sow receiving the basal ration plus 10 percent alfalfa meal that was allowed to raise 9 pigs.

Table 2 shows the data on the sows and the litters produced.

With the exception of the pigs from one sow, all the pigs farrowed on the first trial in both lots were normal at birth and equally vigorous. There was very little difference in the birth weight of the pigs in the two lots or in the total number of pigs farrowed per sow. One sow fed the basal ration farrowed 11 congenitally malformed pigs. They were large and vigorous otherwise. A decided weakness was apparent in the hind legs. This sow weaned three pigs and the leg weakness during the suckling period became steadily worse in each case.

Trial 2 was designed to further test practical supplements and certain vitamins or vitamin concentrates. Four gilts produced by the sows on the first trial fed the basal ration plus 10 percent alfalfa meal were placed on the basal ration and two on the basal ration plus 10 percent alfalfa meal. Two gilts produced by the sows of the first trial fed the basal ration were continued on that ration. These gilts were never off concrete floors and never had access to green forage. They will be referred to as second generation gilts. The rest of the gilts used in trial 2 came from the herd and when approximately 55 pounds in weight were placed on experiment. These are called first generation sows. The second trial was conducted under the same conditions as outlined for trial 1.

The rations and supplements added are shown in table 2. The supplements, tankage, fish meal, molasses, dried brewers' yeast, soybean lecithin, inositol, and para-aminobenzoic acid were added to the rations indicated approximately 10 days before parturition and continued for approximately 20 days after farrowing.

The incidence of congenital malformations was greater in the second trial especially in the litters produced by the second generation sows. Four of the six second-generation sows produced litters with 75 to 100 percent abnormal pigs. Some malformations were observed in litters from first generation sows receiving either the basal ration, basal ration plus 10 percent alfalfa meal, or basal ration plus 5 percent bran and 5 percent middlings.

The malformation observed in the newborn pigs of both trials ranged from the previously observed "sickle hock" in the mild cases to syndactylism and dysostosis resulting in vestigial limbs and paralysis agitans. Mild expressions of the disease appear as sharply "kinked tails" or sickle hock (figure 1). The next stage showed the dysostosis of the hind feet which results in talipes, syndactylism, increase or decrease in the number of toes or dew claws, and extensive edema of the thigh region of the hind legs which may extend into

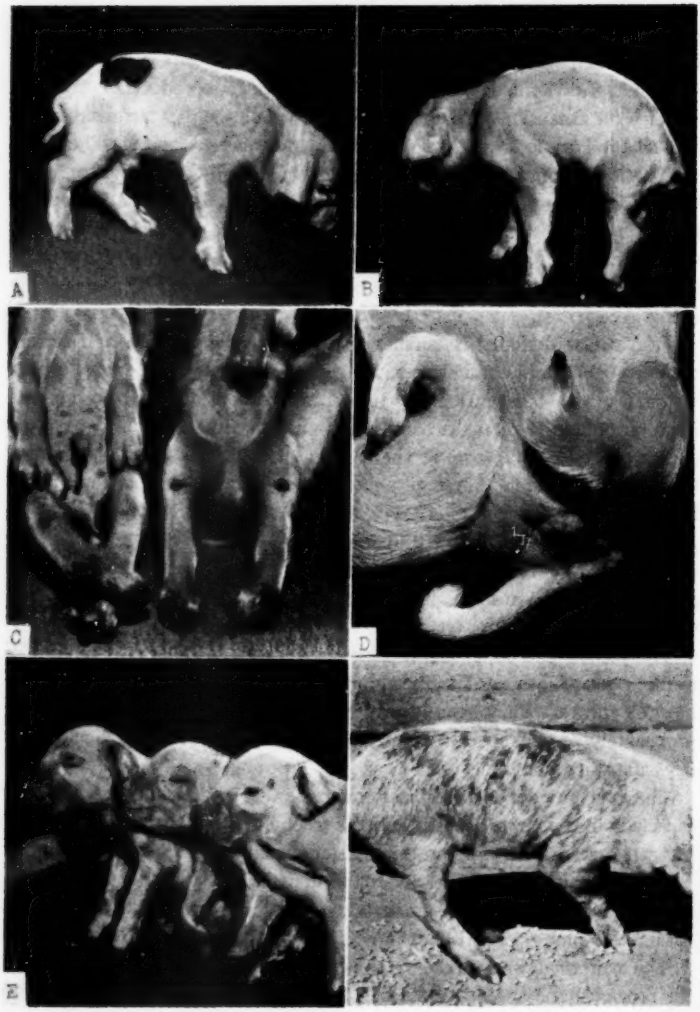

Figure 1. Abnormalities caused by deficient natural occurring ration. A—Early evidence of the deficiency—kinked tail and sickle hocks. B—Talipes and kinked tail—more pronounced deficiency. C—Talipes, syndactylism and edema of hind legs (right). D—Vestigal hind legs—extreme deficiency failure. E—Abnormal, center atrophic and blind, right hypertrophic and blind. F—Characteristic dermatosis and scurf over the back and ears.

the peritoneal cavity (figure 1). The extreme condition was marked by vestigial hind limbs indicating complete dysostosis. In some of the severe cases the eyes were also affected. In two cases abnormally large eyes were observed. The hypertrophy of the eyeball was due to the accumulation of fluid within the eye itself. In one case the eye had atrophied apparently as the result of rupture. In both instances the pigs were blind. It is interesting that two of these pigs with talipes were afflicted with palsy or paralysis agitans, one severely and one mildly. The severe case exhibited the rotary oscillations of the head characteristic of the human case. These pigs could not nurse because of this affliction. They would stand and attempt to nurse until exhausted and then lie down and rest for a while, rise and again attempt to obtain food. They died of starvation.

Most of the deaths in the litters of the sows fed the basal ration and the basal ration plus 5 percent bran and 5 percent middlings occurred during the first four weeks. The pigs became very weak and emaciated, scoured, and ataxia of the hind legs appeared. Their hair was harsh and a brown exudate was found adhering tightly to the skin (figure 1). Postmortem examination showed the stomachs to be full of milk. In some instances there was evidence of gastritis. In those pigs surviving the four-week period the skin became rough, wrinkled, and covered with a brown exudate, with considerable loss of hair. The pigs were unthrifty and exhibited in some instances a sickle hock condition. The pigs from the sows receiving the additional amounts of alfalfa meal were more thrifty looking, and the characteristic symptoms described in the afflicted pigs were in much less evidence.

An attempt was made to correct, by vitamin therapy[2], the condition described in the pigs of one litter produced by a sow fed the basal ration. No apparent growth stimulation was evident at the end of 10 days as a result of feeding various vitamin combinations such as pyridoxine and choline; pyridoxine alone; pyridoxine and soluble liver extract;[3] and 1-20 liver concentrate powder.[3] Further supplementation with calcium pantothenate; calcium pantothenate and riboflavin; and wheat germ oil produced no growth stimulation within a 10-day period.

Two of the sows fed the basal ration were rebred and allowed to farrow their second litter. These pigs were fed various B-vitamin supplements. Various combinations such as solubilized liver extract;[3] alpha tocopherol; 1-20 liver concentrate powder; shark liver oil; wheat germ oil; ascorbic acid; riboflavin, choline chloride, calcium pantothenate, nicotinic acid, pyridoxine, and thiamin failed to bring about the resumption of growth and also failed to prevent the onset of symptoms previously described during a 15-day period. No improvement in appearance or weight could be detected within a

[2] We are indebted to Merck & Co., Rahway, N. J., for the crystalline vitamins used.
[3] Wilson and Co., Chicago, Ill.

16-day period by the addition of either ascorbic acid or ascorbic acid and shark liver oil.

The sows fed the basal ration were in noticeably better flesh when the pigs were weaned than the sows receiving the additional amounts of alfalfa meal. This may have been due either to the fewer pigs suckled per litter, to the quantity or quality of milk produced, or to a relatively larger feed consumption. The sows receiving the additional amount of alfalfa meal lost weight rapidly and began to dry up after about 6 weeks. In a few instances, to protect the sows it was necessary to wean the pigs before the 8 weeks. Because of this condition, the pigs in most cases were as heavy at 6 weeks of age as at 8 weeks. This group of sows raised to weanng more of the pigs given them to suckle. The appetites of this group of sows were affected as was shown in the lower feed consumption which became marked after about the fourth week. This lower feed consumption, apparently greater milk production, and bulkiness of the ration were considered responsible for the greater loss in weight in the sows receiving the basal ration plus 10 percent alfalfa as compared to those on the basal ration.

Discussion

The data presented in table 2 show that the sows fed the basal ration with the 5 percent level of alfalfa meal in trial 1 did conceive and give birth to living young which were normal except for malformations of the feet and legs. The number of pigs farrowed compared favorably with that of sows fed the basal ration plus 10 percent of alfalfa meal (total alfalfa meal 15 percent). The sows of trial 1 fed the 5 and those fed the 15 percent alfalfa meal rations produced pigs that weighed approximately the same at birth and they appeared to be of equal vigor. Considerable difference was seen, however, when the two lots of sows were carried through the lactation period. Those sows in trial 1 which received the basal ration plus 10 percent alfalfa meal weaned nearly 100 percent more and 25 percent heavier pigs at 56 days of age than the controls.

Those pigs produced by the sows fed the basal ration containing only 5.00 percent alfalfa meal were very unthrifty in appearance, showed some digestive disturbances, ataxia of the hind legs, and abnormalities of the skin and hair. Conditions similar to these were described in suckling pigs by Hogan and Johnson (1935, 1940) when commonly used feedstuffs were fed to the sow in dry lot.

Vitamin supplements fed pigs suckling the sows which received the basal ration, produced no stimulation in growth or change in general appearance. Certain members of the vitamin B complex, at the levels fed, and given by capsule either singly or in combination, had no beneficial effect upon these

pigs. Vitamins A and D, fed as shark liver oil, or vitamin E fed as pure alpha tocopherol or wheat germ oil, produced no outward change in appearance or increase in rate of growth. At the levels fed, neither 1-20 liver concentrate powder nor soluble liver extract powder changed the condition of the pigs. Ascorbic acid fed with or without shark liver oil did not benefit these suckling pigs.

Congenital malformations were observed in all litters from the sows used in trial 2. The incidence of malformations was greater in those litters from sows fed the basal ration in trial 2 than those fed the same ration in trial 1. Some abnormalities were observed in litters of sows fed the basal ration plus 10 percent alfalfa meal in trial 2, whereas no abnormalities were observed in sows receiving the same ration in trial 1. Those sows receiving the basal ration plus 5 percent bran and 5 percent middlings reacted much the same as the sows on the basal ration, indicating the ineffectiveness of bran and middlings to correct the deficiencies of the ration. The greater incidence of congenital malformation, poorer livability and smaller weaning weights of trial 2 as compared to trial 1 is partly attributed to the use of a poorer quality alfalfa meal in trial 2 than that used in trial 1.

Second generation sows produced a higher persentage of malformed pigs than first-generation sows suggesting a greater degree of depletion of the nutrients needed to prevent such embryological abnormalities. That the cause of the abnormalities was hereditary could hardly be involved since the sows were bred to boars of other breeds.

Practical supplements such as tankage, fish meal, molasses, and dried brewer's yeast when added late in the gestation period (10 days before parturition) failed to prevent the occurrence of the abnormalities or nourish the sow in such a way as to prevent the onset of the symptoms previously described in the suckling pigs.

Para-aminobenzoic acid or inositol when added singly to the ration of sows 10 days before parturition failed to prevent the occurrence of congenital malformations or to increase materially the livability or weaning weights of the pigs. When added together to the ration some effect was observed upon the livability and weaning weights but abnormalities of the pigs at birth was not prevented. Soybean lecithin which contains both inositol and cholines seemed to increase the livability but had no effect upon the weaning weights or occurrence of deformities in the pigs.

While the addition of 10 percent alfalfa meal to the basal ration in both trials did not completely supplement the ration so that normal reproduction and lactation resulted, it is felt that the factor or factors responsible for these normal processes is present in alfalfa meal of good quality. Alfalfa meal varies greatly, however, in its content of this factor or factors.

Summary

Congenital malformations such as syndactylism, talipes, and paralysis agitans of nutritional origin were produced in swine. The basal ration used in these experiments was found to be deficient in a factor or factors necessary to support normal reproduction and lactation in the sow.

Reproduction of the sow when fed the basal ration was defective as shown by the embryological abnormalities, and lactation was extremely poor, as is indicated by the number, appearance, and weight of the pigs when weaned. Supplementing the milk diet of the suckling pigs from sows fed the basal ration with pyridoxine, choline chloride, solubilized liver extract, 1-20 liver concentrate powder, calcium pantothenate, riboflavin, wheat germ oil, alpha tocopherol, shark liver oil, nicotinic acid, thiamin, and ascorbic acid either singly or in various combinations (at the levels used) failed to improve the appearance of the pigs or accelerate growth.

Good quality alfalfa meal when added to the basal ration carries a factor or factors which wholly or in part corrects the deficiencies of the basal ration. Alfalfa meal varies greatly, however, in the potency of this factor or factors.

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FURTHER OBSERVATIONS ON THE DIETARY INSUFFICIENCY OF A CORN-SOYBEAN RATION FOR REPRODUCTION OF SWINE

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Introduction

IT IS becoming increasingly evident that specific dietary factors are concerned directly with reproduction in swine. Ross, Phillips, and Bohstedt (1941, 1942) have shown that a failure of reproduction occurred when brood sows were fed a practical corn-soybean oil meal-alfalfa ration. The deficiencies of this ration were more acutely manifested in the second generation than in the first as shown by abnormalities occurring in the pigs at birth. They interpreted their results as an indication that at least two unknown factors were involved in reproduction in swine. Hogan and Johnson (1940) likewise have shown that certain practical rations are inadequate for reproduction in swine.

This study was undertaken to determine if certain vitamins or commercial preparations would adequately supplement a practical corn-soybean oil meal-alfalfa meal (5%) ration for reproduction and lactation with sows.

Experimental

Seven lots of sows were selected. Poland China, Chester White, and F_1 Chester White-Yorkshire crossbred sows were used. Each sow was crossed with a boar of another breed to eliminate the possibility that some genetic factor in one breed was responsible for the abnormal pigs obtained at birth from sows fed this ration.

The sows used were approximately 10 months of age and averaged 275 pounds in weight. These sows had been in dry lot and records kept to check the effect of rations during growth on reproductive efficiency.

The 7 rations that were fed these sows are shown in table 1.

In all lots, irradiated yeast[2] was added to each ration at a level of 0.2 pound per 100 pounds of feed. Each sow was also given 2 ml. of shark-liver oil[3] per week. These two supplements were added in order to make sure that vitamins A and D were supplied in adequate amounts. Vitamin A was added

[1] Animal Husbandry and Biochemistry departments, Madison, Wisconsin. This work was supported in part by Wisconsin Alumni Research Foundation and Commercial Solvents Corporation, Terre Haute, Indiana.

[2] Obtained through the courtesy of Stratton Grain Co., Milwaukee, Wisconsin.

[3] Kindly supplied by Bioproducts Corporation, Astoria, Oregon.

TABLE 1. RATIONS FED

Feeds	Lot 1*	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7
Gr. yellow corn	80.5	73.0	80.0	80.5	79.5	80.5	80.5
Soybean oil meal	13.0	10.5	12.5	13.0	12.0	13.0	13.0
Alfalfa meal	5.0	15.0	5.0	5.0	5.0	5.0	5.0
Bone meal	.5	.5	.5	.5	.5	.5	.5
Gr. limestone	.5	.5	.5	.5	.5	.5	.5
Iodized salt	.5	.5	.5	.5	.5	.5	.5
B-Y Riboflavin supplement	—	—	1.0	—	2.0	—	—
Crystalline Riboflavin	—	—	—	125.4 mg. per 100 lb. feed	—	—	—
Choline chloride	—	—	—	—	—	65 gm. per 100 lb. feed	—
Vitamin B_6	—	—	—	—	—	—	.83 gm. per 100 lb. feed
Soybean lecithin	—	—	—	—	—	—	.12 lb. per sow per day

* Basal ration.

especially since the work of Hale *et al.* (1935) had shown that sows deficient in vitamin A gave birth to abnormal pigs.

The sows were housed in a barn which had concrete flooring and runways. They were fed morning and evening at regular intervals. Care was taken to keep them in thrifty condition without becoming too fat. The sows were farrowed in thoroughly cleaned and disinfected pens. As each sow farrowed a few of the young were autopsied for histopathologic study.

Parallel experiments with the rat have corroborated closely the results obtained with sows fed similar rations.

TABLE 2. THE EFFECT OF ALFALFA ON BROOD SOW PERFORMANCE

Lot	No. sows	Ration fed	Litter record				
			Pigs farrowed	Abnormal pigs	No. pigs weaned	weaning wts. at 56 da.	No. sterile sows
I	4	Basal	11	2	6	26	3
II	4	Basal+10% alfalfa	39	0	23	20	0

Results

Table 2 shows the effect of supplementing the basal ration with 10 percent of alfalfa at the expense of corn. These data show that poor reproduction was obtained on the basal ration. Sterility was high and the pigs weaned were extremely rough and unthrifty in appearance. The type of pigs weaned from sows fed the basal ration is shown in figure 1. These pigs exhibited a harsh rough hair coat and a dark brown exudate over the entire surface of the body. All the pigs scoured toward the latter partof the suckling period.

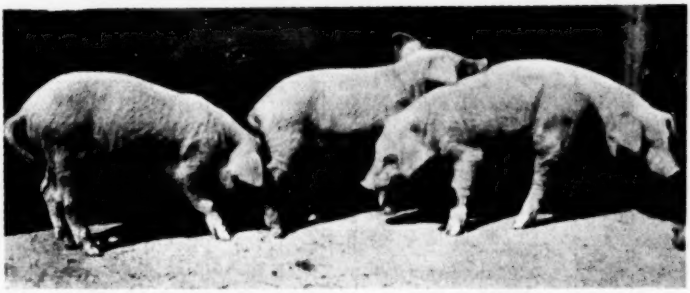

Figure 1. Deficient pigs from sows fed the basal ration only.

Normal reproduction was obtained in lot II where the ration included 15 percent of alfalfa meal. However, the lactation response was not quite normal since the weaning weights obtained with the pigs were low. The type of pigs weaned is shown in figure 2.

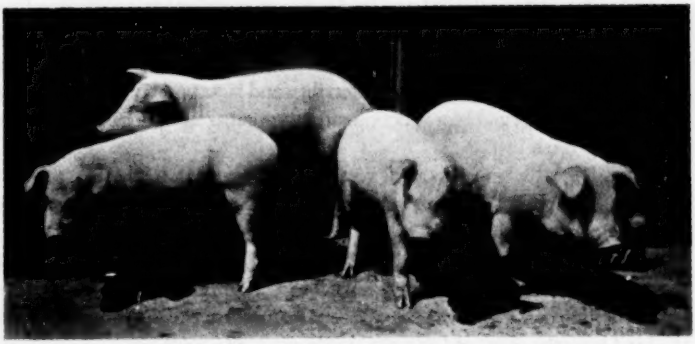

Figure 2. Normal pigs from sows fed the basal ration +15% alfalfa.

Table 3 shows the results obtained when the basal ration was supplemented with certain vitamins and vitamin-rich commercial preparations. The addition of crystalline riboflavin to the basal ration in lot IV was found to be detrimental. Sows fed this ration gave birth to a number of arbnormal pigs and 75 percent of all pigs died before weaning. Likewise, the supplementation with choline in lot VI did not improve the performance of sows over those fed the basal ration alone. Approximately 95 percent of these pigs were abnormal at birth and all the pigs succumbed within a week.

TABLE 3. THE EFFECT OF VARIOUS SUPPLEMENTS ON BROOD SOW PERFORMANCE

Lot	No. sows	Supplements added to basal ration	Litter record				
			Pigs farrowed	Abnormal pigs	No. pigs weaned	Av. weaning wts. at 56 da.	No. sterile sows
III	5	1% B-Y riboflavin supplement	16	9	0	0	2
IV	4	Riboflavin	27	7	7	19	1
V	5	2% B-Y riboflavin supplement	44	23	20	22	0
VI	3	Choline	16	15	0	0	1
VII	3	Soybean lecithin+pyridoxine	20	0	14	22	1

B-Y riboflavin supplement, a by-product of alcohol fermentation from grain or molasses, which is rich in riboflavin as well as other B-complex vitamins was tried. The addition of one percent of the B-Y supplement to the ration fed the sows in lot III was ineffective in supplementing the basal ration. Slight abnormalities were observed in some of the pigs and all the pigs succumbed within a week after birth. However, the addition of two percent B-Y riboflavin supplement improved fertility and lactation but failed to bring about complete normal reproduction since a number of abnormal pigs were obtained at birth.

In lots III–VI where abnormal pigs were observed at birth, post-mortem examination revealed milk in the stomachs of these pigs, but most of the abnormal pigs died within one week after birth.

The deficiencies of the basal ration resulting in abnormalities manifest themselves first by causing kinked tails. This condition is present when there is a borderline deficiency. As the deficiencies increase the pigs are affected in the hind legs, the eyes, and in most severe cases, the front legs.

The occurrence of the various types of abnormalities is summarized in ta-

ble 4. The data show that the most severe abnormalities were obtained in lots V and VI, while no abnormalities were observed in lots II and VII.

TABLE 4. ABNORMALITIES OBSERVED

Lot	Abnormalities
I	Born in process of resorption
III	Kinked tails
IV	Kinked tails, deformed ear, and sickle hock
V	Kinked tails, club feet, sickle hock, extra dew claws, and vestigial hind legs
VI	Kinked tails, club feet, extra dew claws, extra toes, large blind eyes, sickle hock, crooked underdeveloped legs, and vestigial hind legs

Normal reproduction was obtained in lot VII with the sows fed soybean lecithin plus vitamin B_6. This is in agreement with previous work at this station where the addition of either inositol or soybean lecithin to the basal ration proved somewhat beneficial for reproduction and lactation of swine. This corroborates experiments with the rat which have shown that some unknown factor or factors present in liver in combination with inositol, choline, and vitamin B_6 adequately supplements the basal ration for reproduction and lactation. In this species an unknown factor or factors is postulated since addition of all the B-complex vitamins including a folic acid concentrate[4] and crystalline biotin to the basal ration did not result in normal reproduction and lactation. Since soybean lecithin contains three percent inositol and three percent choline, it appears that it also supplied the unknown factor or factors present in liver which are needed in addition to pyridoxine, choline, and inositol to adequately supplement the basal ration.

One sterile sow was obtained in lot VII. Examination of her record showed that she had been on the basal ration during her growth period. Furthermore seven of the eight sterile sows on this experiment were fed the basal ration during their growth period previous to being put on these rations for reproduction tests. Thus the ration the sows received during their growth period had a very marked effect on the subsequent reproductive performance. Further investigation showed that six other sows had been on the basal ration during growth but they evidently had enough storage of the factors needed for reproduction since they gave birth to normal pigs However, in each case the reproductive performance of these sows was the poorest of the lot in which they were placed regardless of the experimental ration fed.

The evidence for the effect of ration during growth on reproductive performance is shown in table 5. These data show that the ration fed during growth is very important later in brood sow performance. The two sows,

[4] Made according to the method of Hutchings, Bohonos, and Peterson (1941).

372 and 20 in lot V, which had been on the basal ration during their growth period performed very poorly in comparison with the other three sows which had been on adequate rations during their growth period. This observation was supported by the record of every sow which had been on the basal ration during her growth period.

TABLE 5. EFFECT OF PREVIOUS RATION ON BROOD SOW PERFORMANCE

Lot	Sow no.	Ration previous to experiment	Experimental ration	No. of pigs farrowed	No. of abnormal pigs	No. pigs pigs weaned	Av. weaning wt. at 56 da.
							lb.
V	372	Basal	Basal+2% B-Y	7	7	0	0
	20	Basal	Basal+2% B-Y	14	13	3	24
	44	Basal+10% alfalfa	Basal+2% B-Y	6	3	3	29
	352	Basal+10% alfalfa	Basal+2% B-Y	9	0	8	20
	652	Basal+2% tankage+ 4% linseed meal	Basal+2% B-Y	8	0	6	19

Discussion

The addition of either crystalline riboflavin or choline alone to the basal ration proved detrimental. This ration is deficient in a number of factors and the addition of one factor of the B-complex without the others accentuated the deficiencies of the ration. This has been a consistent finding with the addition of certain vitamins to this basal ration for the rat (Cunha *et al.* 1943). This may be due to some interaction of the vitamins, to some effect on intestinal synthesis or absorption, or another unknown cause. These experiments therefore suggest that the addition of crystalline vitamins singly or in combination to hog rations may prove detrimental rather than beneficial.

Summary and Conclusions

The single addition of either crystalline riboflavin, choline or one percent B-Y riboflavin supplement to the basal ration proved an ineffective supplement and in some cases a deleterious one. The addition of two percent of the B-Y riboflavin supplement improved fertility and lactation but failed to prevent the appearance of abnormalities in the new born.

Normal reproduction was obtained by supplementing the basal ration with either 10 percent alfalfa meal or soybean lecithin plus pyridoxine. However, in both cases lactation was not quite normal, weaning weights of the pigs being low.

Data are presented to show that the ration sows receive during growth

markedly influences subsequent successful performance in reproduction and lactation.

It is concluded that a practical ration of corn, expeller soybean oil meal, five percent alfalfa meal plus mineral supplement is inadequate as the sole ration for brood sows under dry lot conditions. This ration requires one or more as yet unidentified factors for normal reproduction including lactation. Inositol, pyridoxine, and choline likewise appear to be required in supplemental amounts. Further it has been shown that dietary sufficiency for the growing and developing sow is essential for subsequent successful reproductive performance.

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THE RELATIONSHIP BETWEEN CERTAIN BLOOD COMPONENTS AND RATE OF GROWTH IN SWINE[1]

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Introduction and Literature

STUDIES on heritability of growth in pigs up to market age indicate that about 30 percent of the variance in growth rate is genetic. This allows for considerable opportunity for further improvement by conventional methods of selection; however, greater progress could be made if a more accurate evaluation of true hereditary capacity for growth were possible. Since growth is fundamentally the product of numerous physiologic reactions it is possible that genotype for growth might be more effectively evaluated by measuring some physiological process—provided such a process were subject to less environmental variation, relatively, than growth itself. Many substances that reflect physiological activity are contained in the blood, and therefore the relationship between various blood constituents and the ability of an animal to grow offers one approach to the problem. The identification of a reliable blood index for growth would aid in accurate evaluation of hereditary growth rate, and also allow early selection of breeding stock.

Literature bearing on this subject is not extensive. Gregory *et al.* (1933, 1935, 1937) found greater concentrations of glutathione in the young of a large species of rabbit, than in a small species. They reported this substance in chickens correlated with rate of cell proliferation at 14 days incubation and also with post-hatching growth rate and adult body size.

Willham and Craft (1939) observed that faster growing outbred pigs had a higher hemoglobin level than slow growing inbreds.

Kushner (1938, 1940) found that hemoglobin and red cell counts were higher in mules than in either of the parent species. He reported that these same constituents were associated with body weight of sheep both within and between breeds.

Patrushev (1940) reported that glutathione and blood catalase were also associated with body weight. He believed that blood analysis may serve

[1] Paper No. 2156 Scientific Journal Series of the Minnesota Agricultural Experiment Station in cooperation with the Regional Swine Breeding Laboratory, Ames, Iowa, Bureau of Animal Industry, U. S. Department of Agriculture. Assistance in this work was received from the personnel on W.P.A. Official Project No. 165-1-71-124, Subproject 495, sponsored by the University of Minnesota in 1941. This paper is condensed from Part II of a thesis submitted by the senior author to the Graduate Faculty of the University of Minnesota in partial fulfillment of the requirements for the degree of doctor of philosophy.

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as an additional criterion for evaluating the constitution and breeding qualities of an animal.

Material and Methods

The animals used in this study were taken from the inbred herds maintained by the University of Minnesota in cooperation with the U. S. Regional Swine Breeding Laboratory.

Experimental errors of red cell counts, and of hemoglobin, serum protein, blood catalase, and glutathione determinations were estimated in a preliminary study. The demonstration of statistically significant differences between pigs was considered a prerequisite to justify further investigation of any given blood constituent. Five pigs were used in this trial and under the conditions of the experiment this prerequisite was fulfilled by all except glutathione. These results are not reported. In experiment I the change in the level of the various blood constituents with age of pigs and different lines of breeding was measured. Experiment II was a field test to determine the relationship of hemoglobin and serum protein with rate of growth.

All blood samples were taken from the tails of the pigs. Samples for serum protein determinations were allowed to clot. All other determinations were made on blood samples treated with one drop of saturated potassium oxalate per each ml. of blood.

Red cell counts were made on a hemocytometer.

Hemoglobin was determined as oxyhemoglobin using the Evelyn photoelectric colorimeter (Evelyn, 1936).

Serum protein was determined by coagulating the protein with sulfasalicylic acid and measuring the opacity colorimetrically. The colorimeter was calibrated with samples of serum on which nitrogen was determined by the Kjeldahl method (Looney and Walsh, 1939).

Catalase activity of whole blood was determined by titrating with 0.1 N $KMnO_4$ the excess of H_2O_2 in a standard concentration to which .001 ml. of blood had been added (Bach and Zubkowa, 1921).

The statistical methods employed are based mainly on analysis of variance and covariance (Snedecor, 1940).

Results

Experiment I.—A comparison of certain blood constituents of five inbred lines of pigs at different ages.

Forty-five pigs representing five different lines of breeding were used in this study. Pigs of the Minn. No. 1, Black Star, Viola and M lines, farrowed at different sub-stations in the spring of 1941, were shipped to the central laboratory in St. Paul after weaning. The C_1's were farrowed at the central station. The origin, breed, degree of inbreeding, and number of pigs and

litters representing these various lines and used in this experiment are given in table 1. The lines were quartered separately in adjoining pens and all animals were self-fed standard rations in dry lot. Three pigs died before they reached 140 days. Blood samples were taken at 70, 84, 112 and 140 days of age.[3]

TABLE 1. THE ORIGIN, BREED, INBREEDING AND NUMBER OF PIGS FROM THE LINES USED IN EXPERIMENT 1

Line	Origin	Breed	Coefficient of inbreeding (Wright's)	No. of pigs	Litters represented
Minn. No. 1	Grand Rapids	*	.22	10	3
Black Star	Crookston	Poland China	.34	10	3
Viola	Morris	Poland China	.27	10	5
C^1	St. Paul	Poland China	.19	10	3
M	Waseca	Poland China	.69	5	2

* The Minn. No. 1 line was developed from a crossbred foundation of Tamworth ×Danish Landrace (See Winters *et al.*, 1943).

The averages at different ages are given in table 2. There appears to be no significant change in blood composition from 70 to 84 days of age, but all constituents show an increase in concentration at 112 days. The M line is consistently lowest in all components. This line is the slowest growing and the most highly inbred. On the other hand, the Minn. No. 1 line had the greatest concentration of red cells and hemoglobin whereas the Black Star's the highest in serum protein and catalase at 112 days. These two lines are characteristically fast growing and not as highly inbred as the M line.

Table 3 contains an analysis of variance for the 84th and 112th day periods. Age differences are significant for all constituents. Line differences are significant for red cells and catalase adjusted for hemoglobin concentration.[4] For hemoglobin and serum protein line differences approach significance.

Litter differences are not significant. However, using the mean squares within age and litters as the error variances, all litter mean squares are significant. This is strictly a test for significance of litter differences plus interaction between age and litters.

In the following experiment hemoglobin and serum protein were selected

[3] Unfortunately, all lots of pigs except the M's developed influenza at about 140 days of age; therefore, the data for the last collection period are not included in the results reported here.

[4] Since catalase is found only inside the red cells, it should be highly correlated with volume of red cells. The correlation between hemoglobin, which may be taken as an index of cell volume, and catalase was found to be .69. Accordingly, it seemed desirable to calculate the variance of catalase activity independent of this influence.

TABLE 2. AVERAGE BLOOD CONSTITUENTS BY LINES AND AGES

Constituent	Line*	Age		
		70 days	84 days	112 days
Red cell count (numbers per .0001 mm.³ of blood)	Minn. No. 1	659	694	756
	B. S.	716	671	746
	V	661	651	706
	M	513	539	561
	C_1	—	—	—
	Av.	654	653	709
Hemoglobin (gms. per 100 ml. blood)	Minn. No. 1	12.5	12.4	13.7
	B. S.	11.1	11.1	13.0
	V	11.8	11.7	12.3
	M	10.2	10.6	10.9
	C_1	11.8	12.0	12.9
	Av.	11.5	11.6	12.1
Serum protein (gms. per 100 ml. serum)	Minn. No. 1	5.0	5.2	6.2
	B. S.	5.0	5.1	6.6
	V	5.7	5.3	5.5
	M	4.5	4.6	5.3
	C_1	5.0	5.7	6.4
	Av.	5.1	5.3	6.1
Catalase activity (in ml. equivalents of 0.1 N H_2O_2)	Minn. No. 1	3.7	3.6	4.3
	B. S.	4.5	3.5	4.4
	V	3.6	3.6	4.0
	M	2.8	2.8	3.3
	C_1	3.6	3.5	3.7
	Av.	3.7	3.5	4.0

* Abbreviations refer to lines listed in table 1.

for further study. Since red cell count and hemoglobin are highly correlated it was believed that differences in one would be similar to differences in the other. Due to ease and greater accuracy of determination hemoglobin was chosen. Serum protein was selected because preliminary work indicated it might be the most highly correlated with growth rate. In addition it was more adaptable than catalase to the method of field sampling employed in experiment II.

Experiment II.—Correlation of hemoglobin and serum protein with rate of growth.

In 1942 blood samples were taken from 136 spring pigs included in 49 lit-

TABLE 3. ANALYSIS OF VARIANCE OF BLOOD CONSTITUENTS FOR THE 84TH AND 112TH DAY PERIODS (MEAN SQUARES ONLY)

	d/f[x]	RBC	Hb	Serum protein	Catalase	Catalase adjusted for hemoglobin
Age	1 (1)	54,406**	20.54*	11.67*	6.82*	1.42*
Lines	4 (3)	71,794*	8.70	2.39	1.52	1.19*
Age×lines	4 (3)	1,651	1.90	1.04	.48	.16
Litters within lines	11 (9)	11,420	3.77	0.85	.42	.26
Age×litters within lines	11 (9)	6,099	1.55*	0.38*	.24	.14
Within age and litters	51 (38)	4,425	.70	0.14	.14	.08

* $P < .05$. ** P01.

[x] The numbers in parentheses are the degrees of freedom for red cell counts. Numbers not in parentheses are the degrees of freedom for all other analyses.

ters and representing 7 lines of breeding. Most samples were taken between the 105th and 119th day of age. Within this period age effects were found to be negligible. The pigs were weighed at 56, 112, 114 and 168 days. Gains were calculated from 56 to 112 days and from 114 to 168 days in order to avoid errors in weighing having correlated effects on gains in the two periods.

Samples of blood were collected from pigs located at 3 different stations and preserved on ice until they were analyzed. Most samples were analyzed within 24 hours; a few were not analyzed up to 48 hours of age. Mild hemolysis of a few serum samples was found to be unimportant.

The averages by lines and certain crosses are presented in table 4.

TABLE 4. AVERAGE HEMOGLOBIN, SERUM PROTEIN AND GAINS BY DIFFERENT LINES

Line	Station	No. of pigs	No. of litters	Hemoglobin in grams per 100 ml. of blood	Serum protein in grams per 100 ml. of serum	Gains from 56–112 days	Gains from 114–168 days
Minn. No. 1	N. C.	31	11	12.5	6.7	75	100
B.S.	N. W.	34	12	11.5	6.4	70	97
M.L.	N. W.	17	6	11.6	6.5	70	95
Yorkshire× B.S. & M.L.	N. W.	15	6	10.3	6.3	61	88
M	S. E.	30	11	10.2	5.7	55	86
Duroc×M*	S. E.	9	3	12.3	6.8	78	98

* The Duroc Jersey sire, about 45% inbred, was obtained from the Oklahoma Agricultural Experiment Station. The sows to which he was bred were about 65% inbred.

The M line was again the lowest in hemoglobin and serum protein and the poorest in gains. The Minn. No. 1's and Duroc×M's exhibited the highest blood values and the best gains in both periods. The Yorkshire×M.L. and B.S. crossbreds were second to the poorest in rate of growth and blood constituents. It is interesting to observe that the two crossbred groups occupied almost the extreme positions in blood values and gains.[5] Possibly pigs of one cross possessed more hybrid vigor than those of the other.

From an analysis of variance and covariance total correlations[6] and intra-litter correlations were calculated for the two blood constituents and the two periods of growth. These correlations are given in table 5.

TABLE 5. TOTAL AND INTRA-LITTER CORRELATIONS BETWEEN HEMOGLOBIN, SERUM PROTEIN AND TWO PERIODS OF GAIN

Items correlated	Total r (135 d/f)	Intra-litter r (87 d/f)
Hemoglobin×56–112 day gain	.61**	.22*
Hemoglobin×114–168 day gain	.33**	.04
Serum protein×56–112 day gain	.49**	.38**
Serum protein×114–168 day gain	.18*	.06
56–112 day gain×114–168 day gain	.63**	.47**
Hemoglobin×serum protein	.50**	.21*

* $P<.05$. ** $P<.01$.

The total correlation of .18 for serum protein and 114–168 day gain is significant for $P<.05$ while all other total correlations are significant at the $P<.01$ level. This indicates that the fastest growing pigs are generally higher in hemoglobin and serum protein. Since the intra-litter correlations are considerably smaller than the total correlations, inter-litter environmental factors which are correlated, probably have contributed materially to the latter. Nevertheless, the intra-litter correlations of these blood proteins with gains from 56–112 days are significant. On the other hand, gains from 114–168 days show small and non-significant correlations with hemoglobin and serum protein while the two periods of gain are significantly correlated themselves. This indicates that growth already attained by an animal is of greater value for predicting future growth than either of these blood measurements.

[5] At the central station one litter each of a Minn. No. 1, M and an M×Minn. No. 1 cross (out of Minn. No. 1 dam) were sampled at about 112 days. The hemoglobin for these lines in the order given was 11.2, 9.8 and 12.3 gms. respectively; the serum protein was 6.6, 5.9 and 6.6, respectively. The crossbreds showed the best growth and were equal to or better than the Minn. No. 1's in blood values. These litters apparently contracted necro at about 120 days of age and further work with them was abandoned.

[6] The total correlations include the effects of differences between litters, herds, and sampling days in addition to the intra-litter factors. A total correlation is a simple product-moment correlation coefficient.

Discussion

The significant differences observed between age groups for hemoglobin were possibly owing to management. Schwarte (1939) showed that there was a progressive increase in hemoglobin from the 21st to the 168th day for pigs raised in confinement, while the controls on pasture exhibited higher hemoglobin levels at all ages and no progressive change with age was observed. Since age differences for serum protein closely paralleled those for hemoglobin, both might have similar interpretation.

Experiment I gives some evidence that there is an hereditary basis for differences in blood composition. Litter differences were not significant presumably because of the limited degrees of freedom. However, in the case of red blood cells, catalase, and catalase adjusted for hemoglobin, the litter mean squares are significantly larger than the variance within age and litters while the interactions, age × litters within lines, is not significant. If there really is no true interaction then the mean squares within age and litters would be the more reliable error variance with which to test litter differences, since the former is determined by a larger number of degrees of freedom than the mean squares for age × litters within lines. Line differences were significant for red cell count and catalase adjusted for hemoglobin concentration. It is presumed that these differences are mostly genetic although since the lines were kept in separate pens it is possible that there may have been environmental factors peculiar to each pen. It is not believed these were important. Line differences for hemoglobin, serum protein, and catalase were too small to be adjudged significant—although the corresponding line mean squares for these were all more than twice as large as the appropriate error mean squares (litters within lines).

The correlation analysis indicates that hemoglobin and serum protein are associated with growth. However, a comparison of the total r's with the corresponding intra-litter r's raises the question of whether the differences in correlation are genetic or environmental in origin. The intra-litter variance would contain one-half the hereditary variance present within the line plus that due to factors of environment not common to litter mates. The total variance would contain twice the proportion of genetic variance found within litters plus that resulting from genetic differences between lines. In addition, environmental factors common to litter mates and to different herds would contribute to the total variance. However, environmental herd differences (or station differences) would be confounded with genetic differences between lines. It would be difficult to decide, therefore, which of the two types of variances has contributed most to the total variance. The same reasoning would apply to the total covariance.

In view of the smallness of the intra-litter correlations, it seems likely that

correlated environmental factors have contributed most to the total correlations of hemoglobin and serum protein with 114–168 day gains. These two blood constituents are much more highly correlated with 114–168 day gains than with 56–112 day gains. Within litters, the correlations with 56–112 day gains are significant but with 114–168 day gains practically zero. It appears that these blood components reflect, more or less, the condition of an animal at the time of blood sampling and for that reason tend to be associated with growth. The results indicate that these blood proteins are inferior to past gains as an index of an animal's future gains. It follows therefore that measurements of these two blood proteins will not add materially to the efficiency in selecting for growth rate in swine.

Summary

In experiment I a comparison of red cell counts, hemoglobin, serum protein and catalase activity of 5 inbred lines of swine at different ages was made The level of these blood constituents was found to be higher at 112 days of age than at 84. Significant line differences were demonstrated for red cell counts and catalase adjusted for hemoglobin concentration. Significant litter differences could not be demonstrated but litter differences plus the interaction, age × litters, were significant for all blood constituents.

In experiment II a study of the relationship of growth rate with hemoglobin and serum protein indicated that these two blood constituents were related to growth up to the time of blood sampling but not with growth following blood sampling. Past growth was a better index of future growth than either of these blood constituents.

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ABSTRACTS OF PAPERS TO BE PRESENTED AT THE THIRTY-SEVENTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The meetings are scheduled to be held at the Morrison Hotel in Chicago on December 1 and 2, 1944, with a dinner for the honor guest at the Saddle and Sirloin Club at noon on December 3.

Animal Breeding Section

Ralph Bogart, *Chairman*

EFFECT OF REDUCED BAROMETRIC PRESSURE ON RAM SEMEN. F. Accame, Luis Monge and J. C. Miller, *A. & M. College of Texas.*

Altitude has been known to affect reproduction in man and animals for many years. Improvement of native sheep in the high altitudes of the Peruvian Andes is greatly hindered by the lowered fertility of improved breeds at such altitudes. Artificial insemination of native ewes with semen from improved rams maintained at lower altitudes has not proved entirely successful. It was believed that high altitude might exert a harmful effect on semen. The effect of low barometric pressure on ram semen was studied. Semen samples collected from six rams (two Hampshire, two Rambouillet, one Delaine Merino and one Dorset Horn) were submitted to different barometric pressures during different storage periods. Motility was found to be the same in the samples exposed to low pressure as in the controls. Percentage of live sperm followed the same trend in controls as in treated samples, showing no significant difference. Treated samples and controls showed no difference in true abnormal sperm (True abnormal are all abnormal sperm except coiled tails, broken necks and tailless sperm) proportion but there were some differences in coiled tails and tailless sperm. No injurious effect of low pressure could be detected on ram semen. It is concluded that high altitude impairs fertility by means other than its effect on spermatozoa. Probably the effect is on the reproductive system of the animal itself.

EFFECTS OF STILBESTROL ON ESTRUS OF MARES. V. R. Berliner and J. W. Scales, *Mississippi Experiment Station.*

Eight mares with a previous history of being "shy breeders" with silent heat periods and long anestrous like intervals, showed pronounced estrous symptoms 24 hours after subcutaneous injection of 20 mgm stilbestrol in aqueous suspension. Estrus however was not normal since the vaginal and nervous symptoms preceded the true estrual changes in the ovary. Also, subsequent disturbances of the pituitary-ovarian mechanism were grave. Four mares stayed in heat for 7 days, but did not become pregnant to repeated services during the induced estrus that was followed by irregular estrus cycles. In the other 4 mares excessive ovarian activity was demonstrated by the simultaneous appearance of several follicles and the continuous maturation of new follicles, resulting in prolonged estrus lasting up to 36 days. However, in no instance was there permanent ovarian damage through cyst formation and irreversible luteinization. Seven to ten weeks after treatment all mares took up a normal estrous rhythm and 7 mares eventually became pregnant. Only one mare relapsed into silent heat behavior and did not settle. The unfavorable responses were probably due to slow absorption and elimination of stilbestrol crystals resulting in protracted stimulation, for in two other mares with anestrous behavior injected with stilbestrol solution in which the crystals were dissolved by addition of NaOH, the reaction was less rapid, but very favorable: Estrus set in

after 5 days and ovulation occurred on the third day of the 5-day heat period. Both mares became pregnant.

ALTERATION OF THE ESTRUAL CYCLE BY PITUITARY GONADOTROPINS AND PERSISTENCE OF THE EFFECTS UPON REPRODUCTIVE PERFORMANCE IN EWES. L. E. Casida, R. H. Dutt and R. K. Meyer, *University of Wisconsin.*

The effects of two gonadotropic extracts of the pituitary gland were compared when administered to ewes in three stages of the estrual cycle—fourth, eighth, and twelfth days. Four subcutaneous injections of follicle-stimulating extract in one case and of unfractionated extract in the other were used, each being followed by one intravenous injection of unfractionated extract. Thirty ewes were used. Treatment with unfractionated extract increased both the length and variation of the estrual cycles during which treatment was begun. There was no evident effect of follicle-stimulating extract upon the current estrual cycle when treatment was begun on the fourth or twelfth days; the variation was increased, however, when treatment was begun on the eighth day of the cycle. Treatment with either extract shortened the first estrual period subsequent to the end of treatment in the four- and eight-day groups, but in the twelve-day groups the periods were shorter for the unfractionated and longer for the follicle-stimulating extract than for the controls.

Ten ewes conceived from 20 inseminations among the 15 animals receiving unfractionated extract and 14 ewes from 19 inseminations among a like number receiving follicle-stimulating extract. Breeding was begun at the first estrus subsequent to the end of treatment. Neither extract gave any practical gain in controlling the time of estrus so that variation in the time of breeding could be decreased. In general, greater physiological disturbances followed the use of unfractionated than of follicle-stimulating extract.

THE DOSAGES OF OVARIAN HORMONES REQUIRED IN DAIRY CATTLE FOR CERTAIN PHYSIOLOGICAL REACTIONS. J. de Alba and S. A. Asdell, *Cornell University.*

Four doses of 400–500 R.U. of Progynon B will bring a spayed heifer in heat. At higher doses the animals come in heat but do not remain in heat for long. Mucein is produced only by the lower levels of treatment. There is no bleeding at the cessation of estrus, regardless of the amount of estrogen used to induce estrus. Progesterone influences the effects of estrogen when administered in conjunction with or following estrogen injections.

EFFECTS OF SOME ENVIRONMENTAL FACTORS ON THE WEANLING TRAITS OF RANGE SHEEP. L. N. Hazel and Clair E. Terrill, *U. S. Department of Agriculture, Dubois, Idaho.*

The effects, on weanling traits of sex, age of dam, type of birth, year, breeding group, age at weaning and amount of inbreeding were studied on 2183 range Rambouillet lambs born in 1941 and 1942. The average age at weaning was 123.8 ± 11.1 days. The average inbreeding coefficient for lambs in the inbred lines was 7.2 percent while that for lambs in the group used for progeny testing was less than 1 per cent. Differences in weaning weight between ram lambs and ewe lambs, single lambs and twin lambs, and lambs from mature ewes as compared to those from 2 year old ewes were 8.4, 9.2, and 6.4 pounds, respectively. These differences in staple length were—0.44, 0.19 and 0.04 cm., respectively. Ram lambs, single lambs and offspring from older ewes had better type and condition scores and more neck folds. The regressions of weaning weight, staple length, type and condition scores on age at weaning were positive and on percent inbreeding were negative. The seven major sources of variation were responsible for about 35 percent of the total variance in weaning weight and for smaller percentages in the other traits. The differences large enough to warrant adjustment in a breeding program are as follows: Weaning weight for sex, age of dam, type of birth, age at weaning and percent inbreeding; staple length for sex, age of dam and age at weaning; type score for sex, age of dam and type of birth; condition score for age of dam and type of birth; face covering for sex; neck folds for type of birth.

THE RELATIONSHIP BETWEEN SPERMATOZOAN MOTILITY AND THE PERCENTAGE OF LIVE SPERMATOZOA AND FERTILIZING CAPACITY OF BULL SEMEN. John F. Lasley, *United States Department of Interior, San Carlos, Arizona.*

The relationship between percentage of motile spermatozoa, as determined by a modification of the hemacytometer method of Brady and Gildow (1939), and percentage of live spermatozoa, as determined by the opal blue-eosin staining method, was studied in bull semen. A highly significant correlation was found to exist between live and motile spermatozoa ($r = +.615$ for 167 semen samples) and live and progressively motile spermatozoa ($r = +.696$ for 158 semen samples). When the two methods of evaluating semen quality were combined, four different types of spermatozoa were observed. In semen, a few minutes following collection, there was an average of 16.9 percent dead (stained) spermatozoa, 19 percent non-motile, live spermatozoa, 12.5 per cent weakly motile and 51.6 percent progressively motile spermatozoa. In the same semen samples, after a storage period of 4 days, there was an average of 27.7 percent dead (stained) spermatozoa, 37.4 percent non-motile, live spermatozoa, 20.7 percent weakly motile and 14.2 percent progressively motile spermatozoa. The percentage of motile spermatozoa was also correlated with fertility. In those semen samples which contained fewer than 40 percent motile spermatozoa, the average fertility was 54 percent as compared to 69.4 percent in those which contained 61 to 70 percent motile spermatozoa.

THE FACTOR IN EGG YOLK AFFECTING RESISTANCE AND STORAGE POTENTIALITIES OF MAMMALIAN SPERMATOZOA. Dennis T. Mayer and John F. Lasley, *University of Missouri and United States Department of Interior.*

It has been shown, in a series of investigations on spermatozoan resistance to adverse environmental conditions (cold shock, heat shock, low pH shock, and long storage), that a large proportion of the spermatozoa of individual specimens of semen (bull, ram, boar) possess the ability of acquiring resistance while in buffered diluters containing egg yolk. An investigation of egg yolk resulted in the isolation of a heat stable, white, crystal-like substance which is active in dilutions up to 1 part in 250 parts of diluters. This resistance factor protects 34 percent more cells in a semen specimen against a cold shock of 0° C. for 10 minutes than egg yolk. The factor is insoluble in acetone, alcohol, and ether and gives a positive ninhydrin reaction indicating that it may be a protein or a protein complex. An acetone insoluble, alcohol soluble, fraction of egg yolk kills spermatozoa in a few minutes at room temperature. The increased protective action of the purified resistance factor may possibly result from the removal of the detrimental alcohol-soluble fraction of egg yolk.

BODY TEMPERATURE AND RESPIRATION RATE AND THEIR RELATION TO ADAPTABILITY IN SHEEP. J. C. Miller, L. Monge and F. Accame, *Texas A. & M. College.*

It is common knowledge that some breeds of sheep withstand the long hot summers of south Texas much better than others. Observations designed to determine the efficiency of heat disposal in sheep were made on seven breed groups of five ewes each during July and August of 1943 and 1944. Purebred groups consisted of Hampshire, Southdown, Rambouillet and Delaine Merino ewes. Crossbred groups consisted of Southdown X Rambouillet, Suffolk X Rambouillet and Dorset X Rambouillet ewes. All breeds showed an increase in body temperature and respiration rate concurrently with an increase in atmospheric temperature. The degree of increase varied slightly within breed groups and greatly between groups. Purebred Hampshire and Southdown ewes showed the greatest increase in body temperature and respiration rate, followed by Rambouillet, while Merinos were least affected by high atmospheric temperature among the purebred groups. Crossbred ewes of all groups were less affected by high atmospheric temperature than were purebred ewes. Suffolk X Rambouillet ewes maintained the lowest body temperature and respiration rate of all breed groups.

Productivity of the various breeds in the College flock measured in percentage of lambs raised to weaning, average daily gain of lambs to weaning and fleece weight of ewes, is in the

same order as the ability of the ewes to maintain normal body temperature and respiration rate during the periods of high atmospheric temperature. Efficiency of disposal of excess body heat appears to be closely related to adaptability.

INCIDENCE OF INHERITED CELLULAR ANTIGENS IN TWO BREEDS OF DAIRY CATTLE. R. D. Owen, C. Stormont and M. R. Irwin, *University of Wisconsin.*

Genetic comparisons of breeds have been limited by the difficulty of identifying particular genes with the complex characteristics in which the breeds differ. One such characteristic, the antigenic structure of the red blood cells, is now open to analysis. Thirty antigens, each under gene control, have been described. In the present study, the frequency of each of these antigens was determined in samples of 1305 Guernseys and 875 Holstein-Friesians. It was found that the breed differences in "blood phenotype" result from significant differences in the frequency of 25 of the 30 antigens. Seventeen were more frequent in Guernseys, eight in Holsteins; three of the latter lie between the .01 and .05 levels of significance. The antigen frequency in Holsteins ranged from 1 percent having $\bar{P}$ to 78.2 percent having H′, and in Guernseys from 3.3 percent with $\bar{U}$ to 86.5 percent with $\bar{A}$. The breed differences appear to rest for the most part on contrasting frequencies of genes common to the two breeds, rather than on factors fixed in one population and absent in the other. From the standpoint of known antigenic constitution, each breed is evidently capable of producing individuals identical with representatives of the other breed.

MEASUREMENT OF THYROXINE SECRETION RATE IN GROWING AND LACTATING DAIRY ANIMALS. A. B. Schultze and C. W. Turner, *Missouri Agricultural Experiment Station.*

The secretion of the thyroid gland, thyroxine, plays an important role in growth, reproduction and lactation. To what extent differences in growth rate, conformation and intensity of milk secretion vary with the rate of thyroxine secretion by animals of dairy and beef type has been speculated upon but heretofore no method has been available for determining the rate of thyroxine secretion of animals. Recently it was discovered that a series of chemical compounds related to thiourea have the ability of preventing the secretion of thyroxine. By feeding this drug to growing and lactating animals it is possible to inhibit the normal thyroxine secretion. Then by injecting sufficient thyroxine to maintain normal structures and processes and estimate of the normal thyroxine rate may be made. Details of the methods developed will be described. Milk goats when 60 days of age and weighing 20 lbs. have been calculated to secrete about 100 micrograms of l-thyroxine daily. A group of 8 goats in varying stages of lactation and weighing from 66.0 lbs. to 96.0 lbs. were calculated to secrete from 500 to 1000 micrograms of l-thyroxine daily. In other work using growing chickens as experimental animals the rate of thyroxine secretion up to 12 weeks of age in two breeds has been determined. With advancing age and weight, thyroxine secretion per 100 gm. body weight showed progressive decline. The tendency to decline was influenced to some extent by season. (Mo. Exp. Station Jour. Series No. 958).

THE GESTATION PERIOD OF RANGE SHEEP. Clair E. Terrill, *United States Department of Agriculture, Dubois, Idaho.*

The lengths of over 2,500 gestation periods of range sheep have been determined at the United States Sheep Experiment Station and Western Sheep Breeding Laboratory, Dubois, Idaho. Normal periods ranged in length from 141 to 159 days. Rambouillets had the longest gestation periods with an average of slightly over 151 days and Columbias had the shortest with an average of about 148 days. There was little difference between Corriedales and Targhees with averages around 149.5 days. An analysis of the factors affecting the length of gestation was made from 1,638 periods from Rambouillet ewes obtained in 2 years. These periods ranged from 143 to 159 days in length with a mean of 151 days and a standard deviation of 2.25 days. There was a tendency for ewes that were bred early to have slightly longer periods of gestation than ewes that were bred late. There was a fairly constant though slight

increase in the length of gestation with advancing age. Ewes which were 8 and 9 years of age had gestation periods averaging nearly 2 days longer than 2 and 3 year old ewes. The gestation period resulting in a single birth averaged about 0.6 day longer than that resulting in a twin birth. No differences were found due to the sex of the lambs born. The increase in birth weight with longer gestation periods was consistent with the rate of gain to be expected immediately after birth. The rate of survival was slightly greater with longer gestation periods.

GENETICALLY REDUCED PROLIFICACY. W. J. Tyler, *University of Wisconsin.*

A case of partial sterility expressed by both male and female rats, characterized by high prenatal mortality of their offspring, and transmitted to one-half of the offspring of affected parents (Waletzky and Owen, Genetics 27: 173, 1942) has been carried through five generations by mating partially sterile (PS) individuals to normal (N) mates. Matings of PS individuals *inter se* have yielded either one or two young or no young at all. The resorption rate in 108 (PS×N) pregnancies was 57 percent, and in 166 (N×N) pregnancies was 6 percent. The percentage of corpora lutea represented by implantations was about the same in both types of matings (81 percent and 88 percent respectively). Fifty-four males and ninety-seven females raised from control stock under similar laboratory conditions were mated to estimate the normal resorption rate. The average rate was 8 percent and the implantation sites represented 87 percent of the corpora lutea. Genetically determined partial sterility may not occur frequently in rats, but undoubtedly does explain some of the lowered fertility in this species and should be guarded against by appropriate tests when partial sterility is suspected in other classes of animals.

AN ANALYSIS OF THE FACTORS AFFECTING PRODUCTIVE VALUE IN SHEEP BREEDING. L. M. Winters, *University of Minnesota.*

The productivity of ewes was appraised by 7 different methods ranging from returns per head to allowances being made for maintenance of ewe and lambs. The correlations for the various methods with that of allowing maintenance for ewe and lambs, considered most accurate, ranged from 0.91 to 0.98. A study of the regression of different methods of appraisal on weight indicates a slight advantage of the lighter ewes over heavier ewes when maintenance is taken into account. Appraisal on the per ewe basis favors the heavier ewes somewhat and appraisal on the basis of 100 pound ewe weight gives a slight advantage to the lighter ewes. An analysis of what actually happens in flocks culled by the various methods indicates that there is little change in ewes culled regardless of which of the methods studied is used. The factors having most effect on a high return per ewe were (1) survival of lambs, (2) twins, (3) fast gaining lambs, (4) weight of fleece, and (5) quality of lambs. Little relationship was found between lambs' rates of gain from birth to 15 weeks and from 15 to 23 weeks. While these data show a slight advantage of the lighter ewe (within groups) the crossbreeding studies show a decided advantage in the use of rams belonging to the heavier breeds.

Beef Cattle Section

Rex Beresford, *Chairman*

DISTILLERY SLOPS AS FEEDS FOR FATTENING STEERS. W. H. Black and N. R. Ellis, *United States Department of Agriculture,* and W. P. Garrigus, *Kentucky Agricultural Experiment Station.*

This paper covers investigations conducted during the winter 1943–44 at the Meadow Lawn Distillery near Louisville, Kentucky, in which three groups of 700 pound feeders steers were fed slop made from different types of mashes, for a period of 224 days. The slops were fed ad libitum with a fair quality of lespedeza-grass hay, fed at the rate of 5 pounds per head daily for all groups. The steers fed slop made from whole wheat mash consumed 21.94 gallons per head daily as compared to 20.44 gallons for those fed a granular wheat slop and 19.44 gallons for those fed slop made from a mash composed of equal parts corn and wheat. The average

daily gains per steer were as follows: 1.70 pounds for those fed whole wheat slop, 1.50 pound for those fed granular wheat and 1.40 pounds for the steers fed the corn-wheat slop. The carcasses in general had plenty of covering, but lacked marbling, those from the steers fed the whole wheat slop having a slight advantage over the other groups in dressing percent and grade. This test clearly indicates that these slops are usable feeds for beef production and are particularly valuable in areas close to distilleries.

THE UTILIZATION OF UREA BY BEEF STEERS. H. M. Briggs, W. D. Gallup, and A. E. Darlow, *Oklahoma Agricultural Experiment Station.*

Four yearling Shorthorn steers were offered 10 lbs. of a low grade prairie hay daily in metabolism stalls and the resulting apparent digestion coefficients and nitrogen storage were negative. When the paririe hay was supplemented with a daily allowance of 1.5 lbs. of cottonseed meal or a similar intake of nitrogen in urea pellets, or DuPont's "262" mix the apparent digestion coefficients of the rations were within a normal range. The nitrogen balances of the steers were positive when they were fed the cottonseed meal, urea pellets and "262" supplemented rations but were negative when straight urea provided the supplemented nitrogen. All the supplements improved the appetite of the steers and resulted in more normal droppings than the unsupplemented basal rations of prairie hay. Five yearling Angus were fed a grain-hay fattening ration in dry lot in which urea pellets furnished the supplemented N and gained 1.62 lbs. per head daily in a 160 day feeding period. Five similar cattle fed the same ration except that cottonseed meal was used as the supplement gained 2.03 lbs. daily.

THE NUTRITIVE VALUE OF CORN COBS IN BEEF CATTLE RATIONS. Wise Burroughs, Paul Gerlaugh, A. F. Schalk, E. A. Silver, and L. E. Knukle, *Ohio Agricultural Experiment Station.*

Five digestion trials and four feedlot experiments are reported. In the first trial total digestible nutrient values of 59, 43, and 58 were obtained for corn cobs when fed at three intervals of the fattening period. In the second and third trials, average T.D.N. values of 49, 54, and 41 were secured with corn cobs when they made up 10, 20, and 40 percent, respectively, of the corn and cob mixtures fed. The fourth digestion trial, using mixtures of 10, 20, and 30 percent ground cobs in alfalfa hay, gave cob T.D.N. values of 58, 59, and 57, respectively. A T.D.N. value of 50 was obtained in the fifth trial in which cobs made up 90 percent of the ration and dry milk the remainder. The average T.D.N. value for cobs in all determinations was 51 which, compared with a T.D.N. value of 81 for No. 2 corn, indicates that cobs have a fattening value equal to 62 percent of the corn grain. The feedlot investigations included two years work involving 12 lots of cattle in which four comparisons were made between: (1) regular corn-and-cob meal, (2) double cob in regular corn-and-cob meal, and (3) ground shelled corn containing no cob. Calves were used the first year and yearlings the second year. Two lbs. of mineralized S.B.O.M. and about 4 lbs. of mixed hay were fed each steer daily along with a full feed of grain. The gains made on the three rations were very similar. The corn replacement value by the cob averaged 66 percent with the calves and 60 percent with the yearlings. Results suggest that corn cobs are 63 percent as valuable as the grain for fattening steers.

COMPARISON OF DIFFERENT AMOUNTS OF PROTEIN SUPPLEMENT FOR WINTERING BEEF COWS ON FOREST RANGE IN THE SOUTHEASTERN COASTAL PLAIN. J. E. Foster, H. H. Biswell and E. H. Hostetler, *North Carolina Agricultural Experiment Station.*

Three trials comparing the wintering of beef cows on forest range supplemented with two, four, or six pounds of either cottonseed meal or soybean oil meal per head daily have been completed. Each group contained from twenty-seven to thirty-two grade cows, principally of Hereford breeding, which were bred to calve in February, March and April. The supplement was supplied from approximately January 1 to May 1, and a rather complete mineral mixture

was available to the cattle at all times. These studies brought out the practicability of wintering beef breeding cows on forest range. All groups wintered satisfactorily and calved normally, and even the group receiving six pounds of protein supplement per head daily was wintered much more economically than under most farm conditions. Furthermore grazing observations revealed no evidence of pines (which are the type of reforestation desired in that area) being browsed. The losses in weight of the cows were less in the groups receiving the most protein supplement, and the spring and summer gains of the calves were slightly greater in these groups. Most of the difference in gains of the groups of cows during the winter was offset the following summer by the greater gains of the cows that had received the least supplement the preceding winter. However, if cows are wintered too poorly the following calf crops may be materially reduced due to the cows being wintered too poor to breed or conceive during the normal breeding season.

STUDIES ON THE TRICHOMONAD CARRIER-COW PROBLEMS. Banner Bill Morgan, *University of Wisconsin.*

The carrier problem in cows infected with bovine trichomoniasis, a venereal disease of cattle, has not been studied extensively because of the difficulty of obtaining experimental evidence. Observations were limited to 218 cows. One hundred and sixty-seven cows were selected which had been bred by an infected bull and 51 infected cows whose breedings to a normal bull resulted in normal parturition. Samples of the vaginal and fetal fluids were collected weekly for a period of 6 to 8 weeks and examined microscopically for the presence of *Trichomonas foetus*. Only 2 cows were found infected. In one case the organisms were located at the time of parturition and again 3 weeks later. In the second case *T. foetus* occurred once, 6 weeks after calving. Trichomonads were isolated from the vagina of 3 other cows during the gestation period but were not recovered at parturition or afterwards. One cow produced 2 normal calves after service by an infected bull and one normal calf after artificial insemination with clean semen. Following the next service with a clean bull the animal aborted a 4 month fetus. Our observations in one herd definitely indicate that a bull, infected by serving one trichomonad-carrier cow, in turn infected 12 heifers. However, this study was based on methods of diagnosis which are not entirely adequate.

THE FEEDING VALUE OF DRIED MOLASSES BEET PULP AND BEET MOLASSES FOR BEEF CATTLE. H. P. Singleton and M. E. Ensminger, *State College of Washington.*

At the Irrigation Branch Experiment Station, Prosser, Washington, 282 head of yearling and two-year-old feeder cattle in thin condition, grading "good" and "medium," were used in three years' feeding trials designed to determine the feeding value of dried molasses beet pulp and beet molasses as substitutes for a considerable part of the corn, wheat and barley grain rations, using chopped alfalfa hay as the roughage. It was found that beet by-products furnish a desirable substitute for a part of the grain ration, upward of fifty percent of the corn, wheat and barley rations, respectively, having been replaced by beet pulp; whereas with other lots an average daily allowance of 6¾ lbs. of beet molasses was consumed, replacing a considerable amount of the grain ration. Addition of beet pulp did result in some decrease in hay consumption and in gains, especially when feeding large quantities of hay and limited grain. However, the addition of pulp lessened trouble from bloat. The type of ration did not influence quality and finish of the cattle with steers grading "good" and "medium" and fed for a 120-day period. Feed cost per cwt. lbs. gain seemed to be determined by comparative feed prices more than efficiency of feeds used.

Dairy Cattle Section

H. P. Davis, *Chairman*

BLOOD CHANGES IN NORMAL AND MILK FEVER COWS AT PARTURITION. J. W. Hibbs, W. E. Krauss, C. F. Monroe and T. S. Sutton, *Ohio Agricultural Experiment Station.*

Blood samples were drawn for analyses of calcium, phosphorus, magnesium and vitamin D at the following points: 4 weeks pre-freshening, within 12 hours both before and after freshening, and one week post-freshening. Samples were taken during milk fever and through the recovery period. 80 Jersey, 35 Holstein, 21 Ayrshire, and 15 Guernsey freshenings are included in the study. A slight lowering of both blood calcium and phosphorus occurs just before freshening in both normal and milk fever cows. A further decrease occurs just after freshening but is more marked in cows that develop milk fever. During milk fever blood calcium drops to about 40 percent of the normal level and phosphorus to about 30 percent of the normal level, a 75 percent increase in magnesium occurs, while no change is found in the magnesium level in normal cows. High magnesium in relation to low calcium in milk fever may be a possible explanation for anesthetization where tetany would normally be expected. No significant difference was observed in blood calcium, phosphorus or magnesium levels when irradiated yeast was fed as a source of vitamin D.

The vitamin D content of the blood of cows which developed milk fever was considerably lower 4 weeks before freshening than in cows that freshened normally. When 1 million units of vitamin D daily as irradiated yeast was fed, the vitamin D content of the blood increased about 75 percent during the 4 weeks but several cows developed milk fever.

THE IMPORTANCE OF CONSIDERING UNIFORMITY OF GET IN SELECTING PROVED DAIRY SIRES. Leslie E. Johnson, *South Dakota State College.*

A study was made to determine the value of considering the uniformity of gets in fat production when selecting proved sires. Two-hundred and fifty-six sire-progenies were investigated. Variance ($Sx^2/n-1$) was used as the measure of uniformity. The differences in the uniformity of the progenies were large and highly significant. The most uniform get had a range in fat production (difference between lowest and highest producing daughters) of 95 pounds and the most variable one had a range of 728 pounds. Only a small portion of the differences, however, were repeatable in future daughters of the same sires. The best estimate of the relationship between the uniformity of the first ten and second ten daughters of a sire was a correlation of .11 with only .03 being directly attributable to the sire. The sires of the most uniform progenies produced future daughters with a range of only 20 pounds less than those produced by the sires of the most variable gets. The small effect that the sires were able to exert upon the uniformity of their gets was directly associated with their degree of inbreeding and was, therefore, non-hereditary in that it could not be passed from sire to son in other than an inbred population. Thus in the data studied there was no justification for considering the uniformity of fat records of progenies when selecting proved sires. A similar conclusion appears appropriate regarding selection for uniformity in any character which depends upon several gene pairs and which is not highly hereditary.

COBALT DEFICIENCY IN DAIRY CATTLE IN THE UPPER PENINSULA OF MICHIGAN. G. S. McIntyre, C. W. Duncan, J. T. Reid, C. F. Huffman, and B. J. Killham, *Michigan Agricultural Experiment Station.*

An unthrifty condition of dairy cattle has been observed for many years on numerous farms in the Upper Peninsula. In the fall of 1942 an investigation was started in order to determine the extent and cause of this condition. A total of 24 herds were visited from one to four times during 1942–43. Many of the cattle on these farms were affected. The symptoms first observed consisted of a gradual loss of appetite and a rapid loss of condition. Depraved appetite was usually manifest by wood chewing. Symptoms were more frequently observed in calves than among the mature cows. In this study the hemoglobin concentration and the shape of the red cells were determined regularly but plasma calcium, inorganic phosphorus and magnesium were also determined in some herds. The administration of cobalt sulfate brought about a marked improvement in the appetite and condition of the animals as well as an increase in hemoglobin concentration and shape of the red cells. The cobalt was administered in some cases by adding 0.5 oz. of cobalt sulfate to 100 lb. of salt and allowing the animals free access to it. One ounce of cobalt sulfate was dissolved in one gallon of water and 1 tablespoonful of

this solution per day was added to the milk received by each calf for 7 days and then 1 teaspoonful per day thereafter. Since this study was started the use of cobalt as a supplement has increased very markedly and a satisfactory improvement has been noted in the health of the cattle, in milk production and in a normal calf crop.

EFFECT OF DIFFERENT LEVELS OF HAY, NUTRIENT AND FAT INTAKE UPON MILK PRODUCTION. J. K. Loosli and H. L. Lucas, *Cornell University.*

A lattice-square design experiment involving twenty Holstein cows with four periods of six weeks each was used to compare the value of sixteen rations for milk production and body gain. The sixteen diets included three levels of fat, three levels of nutrient intake and two levels of hay feeding. The results obtained and the advantages of the experimental design will be discussed. A preliminary analysis of the data indicated increasing milk and fat production with increased fat intakes, an increased production, and a marked increase in rate of gain with higher nutrient intakes. There was some indication of a higher fat percentage on the high hay level.

A STUDY OF SOME FACTORS IN THE SALIVA OF DAIRY CATTLE WHICH MAY AFFECT DIGESTION AND SYNTHESIS IN THE RUMEN. J. T. Reid and C. F. Huffman, *Michigan State College.*

In a study of the role of rumen flora and fauna, it appeared logical to determine some of the properties and constituents of saliva. This is especially true in view of the large amount of saliva produced and the apparent speed and magnitude of fermentation during and immediately following eating. This investigation involved the determination of the pH, ascorbic acid content, water content and surface tension of 77 saliva samples from dairy cattle. The mean pH value for 23 saliva samples not collected under neutral paraffin oil was 8.71 while a mean pH of 8.53 was found in the other samples, which were protected by oil. The time of collection relative to the feeding time had no apparent effect on the reaction of the saliva. The great surface activity of cow's saliva offered a possible explanation for its efficient deodorizing property, as well as some of its roles in digestion. The average surface tension determined for 55 samples was 47.10 dynes per centimeter, while typical adsorption curves were derived from the passage of benzene vapor through saliva. The surface phenomena displayed by saliva was attended with much interest, especially since the average water content of 36 samples was 99.12 percent. An analysis of 75 saliva samples gave an average value of 0.154 mg. percent ascorbic acid. The average ascorbic acid content of plasma from the same animals was 0.469 mg. percent. The saliva ascorbic-acid content was found to be extremely variable and showed no relationship to the plasma ascorbic-acid level.

STIMULATION OF MILK AND BUTTERFAT PRODUCTION IN COWS FED VARYING LEVELS OF SYNTHETIC THYROPROTEIN. E. P. Reineke, H. A. Herman, C. W. Turner and A. C. Ragsdale, *University of Missouri.*

Using methods recently developed at the Missouri Station it is possible to form a synthetic thyroprotein possessing high thyroidal activity by combining casein with iodine. Previous reports have shown that this synthetic thyroprotein, in common with other thyroidal substances, will produce a significant stimulation of milk and butterfat production when fed to lactating dairy cows. Experiments have been conducted since 1941 with the object of determining the level of thyroprotein most suitable for long time feeding of dairy cows, the physiological effects of excessive doses, and the possible seasonable factors that might influence the response to such material. So that the dosage of thyroprotein used in different experiments can be compared directly, all dosages are expressed on the basis of a preparation containing 3 percent thyroxine, as estimated by chemical analysis. Results of three groups of experiments, conducted in 1941–42, 1943 and 1944, over a dosage range from one-half to 8 grams of thyroprotein daily per 100 lbs. body weight and covering periods from 3 to 7 months are available. One-half gram of thyroprotein per 100 lbs. body weight daily produces a slight but questionable rise in milk fat test, but little or no effect on milk yield. A dosage of 1.0 to 1.5 gms.

caused an increase over paired controls of about 10 percent in milk yield and 15 to 25 percent in fat yield and this increase was maintained for five months while the thyroprotein feeding was continued. (Missouri Agricultural Experiment Station, Journal Series No. 960).

SERIOUSNESS OF THE BLOAT PROBLEM AND CONDITIONS UNDER WHICH BLOAT OCCURS. A. F. Schalk, *Ohio State University.*

Bloat is a serious problem in ruminants. It is accompanied by extremely grave consequences and cogent reasons prevail as to why it should not be dealt with lightly. The gravity of the problem is greatly underestimated by many because they consider only the cold figures of deaths encountered. While immediate losses from deaths are truly significant, many other attendant conditions materially contribute to the accumulated seriousness of the problem. The items and factors chiefly concerned that have a definite place in the problem are: (1) a considerable amount of extra time required and, (2) the additional cost incurred in building up and maintaining proper safeguards for effective preventive control and remedial measures. The conditions under which bloat occurs are probably many and varied. Numerous theories and causes have been advanced, but in the main, they lack substantiation by data gathered from carefully and completely controlled experimental tests. An attempt will be made in this presentation to discuss the more plausible conditions that have been put forward in the light of the accumulated knowledge based upon observation, experience and the limited dependable information recorded from reliable investigational studies.

THEORIES OF BLOAT, C. F. Huffman, *Michigan State College.*

Although the cause of bloat in the ruminant is not definitely known, there are several theories. Some of these are as follows: 1. *Excess gas formation theory.* Bloat is due to the rapid consumption of highly fermentable feeds which results in the production of more gas than the animal can eliminate by belching. The effect of bacteriocidal compounds such as turpentine in the treatment of bloat has been used as an argument in favor of this theory. 2. *Excessive consumption of dense feed theory.* According to this theory bloat is due to physical obstruction of the cardiac orifice by the rapid ingestion of dense feeds such as young succulent legumes that prevents the expulsion of gas. This theory is supported by the general observation that the fast "eaters" are more subject to bloat. 3. *The toxic gas theory of bloat.* According to this theory bloat results from the absorption of either hydrogen sulfide or carbon monoxide, produced in the rumen, which paralyzes the rumen wall. Investigators are not in agreement as to the amount of these two compounds in rumen gas from bloated animals. 4. *Histamine theory.* This theory is based on the fact that the injection of histamine causes a complete paralysis of the rumen, and the increased histamine content of rumen ingesta by feeding high protein rations. Also the ingesta from steers dying from bloat were high in histamine. 6. *The saponin theory.* This theory is based on the assumption that plants which favor bloat are relatively high in saponin. The presence of saponin is believed to result in frothy bloat. 5. *Interference with belching theory.* According to this theory, bloat is due to a lack of sufficient coarse feed to elicit the eruction reflex, or it may be due to a higher threshold of irritability needed to bring about belching. 7. *Abnormal microflora in the rumen theory.* Under some conditions where the rapid consumption of fresh alfalfa occurs, the rumen flora shows increased numbers of pseudo yeast cells. These cells under aerobic conditions in the presence of sugar cause very rapid gas formation.

SOURCES OF RUMEN GASES. Max Kleiber, *University of California.*

Quantitatively the most important rumen gases are methane and carbon dioxide. Hydrogen has not always been observed in samples of rumen gas and hydrogen sulfide is present only in small quantities. Oxygen and nitrogen may enter the rumen in swallowed air or by diffusion from the blood stream. Bacterial production of nitrogen gas is however a possibility. According to Kellner, carbohydrates of the food are the only sources of methane in the rumen because no increase in the rate of methane formation was produced by adding either protein or fat to

a basic ration of steers. The absence of such partial effects, though an index that fats or proteins do not contribute much to methane production, is however no proof against the possibility that rumen gases can originate from compounds other than carbohydrates. The presence of hydrogen sulfide in rumen gas indicates some decomposition of protein-like substances. According to Van Niel's theory methane may originate from carbon dioxide. Carbon dioxide, however, must originate in the rumen itself because its partial pressure there is higher than in the alveoli of the lungs. The ratio of carbon dioxide to methane concentration in the rumen gas is at present no valid criterion for the relative rates at which these two gases are produced in, or given off from, the rumen. More information is needed on gas transfer between rumen and blood stream.

FACTORS INFLUENCING RATE AND TYPE OF GAS FORMATION. T. M. Olson. *South Dakota Agricultural Experiment Station.*

It is generally accepted that bloat is due to an abnormal amount of gases in the rumen and the cause of the accumulation of gas is probably due to the inability of the animal to eructate. It has been demonstrated that animals can endure insufflated pressures of air, far greater than the pressures which prevail when animals bloat as a result of feed. This would seem to indicate that ruminal pressure *per se*, unless sustained and allowed to build up, does not inhibit eructation. Ruminal gases form rapidly for the first several hours when the cow is filling her rumen with feed. Cows usually bloat within the first three hours if they are going to bloat. Fermentation of grass and legumes *in vitro* confirm the rapid rate of gas formation. Obviously the amount of feed consumed and the rate at which it is eaten, influences the amount of ruminal gas formed. The total ruminal gases formed are probably determined by the rate of fermentation regardless of type of feed. However, the type of gases produced may be more important than the total gases in inhibiting belching. The physical condition of the feed is believed to be an important influence in inducing animals to belch and therefore prevent an excess accumulation of ruminal gas. No data are available which indicate the type of bacterial flora in the rumen of animals which bloat. Several trials *in vitro* in which the ingesta of the rumen was subjected to different materials and temperatures failed to disclose any change in rate of fermentation.

EXPERIMENTAL PRODUCTION AND PREVENTION OF BLOAT. H. H. Cole, *University of California.*

The various experimental procedures for producing bloat will be discussed. These include sectioning of the vagi, the use of drugs and special feeding regimes such as the feeding of succulent legumes, grain alone or ground hay and grain. Evidence has been obtained to show that bloat on grain alone is not entirely comparable to that on green legumes. The various means which have been employed in preventing bloat will be considered. Some information on the quantitative aspects of the use of hay as a preventive will be given.

Horse and Mule Section

R. B. Cooley, *Chairman*

GROWTH OF HORSES UNDER WESTERN RANGE CONDITIONS. W. M. Dawson, R. W. Phillips and S. R. Speelman, *United States Department of Agriculture.*

Growth studies are reported on 297 horses (16 Belgian, 59 grade draft, 75 Morgan and 147 grade light) foaled at the U. S. Range Livestock Experiment Station, Miles City, Montana, from 1927 to 1934. The young stock grew normally from birth to 18 months of age under a system of management in which they were adequately fed. Thereafter, when maintained principally on pasturage, they lost weight on the average every winter, and while they made rapid gains on grass the next summer, they matured at a somewhat smaller size than would be expected if they had been well fed throughout the whole growing period. Significant differences in both height and weight were found between the breed groups studied. Males tended to be

larger than females and appeared to mature more slowly. The differences in the sexes increased up to five years of age. Weight was affected more than height by adverse conditions. Yearly variations in growth were significant but not consistent in the various groups.

DESIRABILITY OF DEVELOPING COURSES IN JUDGING, CARE AND MANAGEMENT OF LIGHT HORSES AT AGRICULTURAL COLLEGES. Wayne Dinsmore, *Horse and Mule Association of America, Inc.*

Light horses (Arabs, Thoroughbreds, Quarter Horses, Saddle Horses, Walking Horses, Hackneys, Standardbreds and Morgans) are growing in importance even while the breeds of draft horses are slowly yielding to the increasing use of mechanized equipment on farms and highways. Light horses are used principally for work under saddle on cattle ranches in the 17 most Western states, and to some extent on farms and plantations east thereof. Their secondary use, so far as numbers are concerned, is for pleasure. Those used for pleasure are for (a) racing, (b) showing, (c) polo, (d) pleasure riding. While secondary in numbers, horses used for pleasure have an importance that is much greater than is generally realized. Racing is a source of taxes which aggregate large sums, and a heavy contributor to various charities. Horses used for pleasure riding contribute to the physical and mental development of children who are fortunate enough to be able to ride, and help greatly to maintain the health and vigor of mature persons who ride with reasonable regularity. In addition, and this is most important to the state agricultural colleges which depend upon their legislatures for financial support—the people who own light horses include many of the wealthy, influential citizens of their respective states. Inquiries addressed to the animal husbandry departments of the various state agricultural colleges in August and September, 1944, brought answers from all but four by September 12th. Of the 44 which replied, 17 owned light horses of at least one of the 8 recognized light breeds named above, and 27 owned none at all.

THE TENNESSEE JACK AND MULE BREEDING PROJECT: H. R. Duncan, *University of Tennessee.*

This project was initiated in the fall of 1937 at the Middle Tennessee Experiment Station, Columbia, Tennessee, on a 150-acre tract of land bought for this purpose, at a time when there was a rejuvenation of interest in horses and mules. There was a strong demand for farm mares and the demand for jacks far exceeded the supply. Jacks were selling readily at $1000 each. The high horse and mule population of the twenties with motorization replacement of horses had almost depleted the herds of jacks and jennets. Many herds were sacrificed for hog feed or driven away from home. The project seemed justified from the following standpoints: 1. Preservation of meritorious jackstock for mule production. 2. Improvement in jackstock and the fixing of a type to meet present day demands for mules. There seems to be less uniformity and dependability in the transmission of various characteristics in jackstock than in other classes of livestock. 3. A constructive mule breeding program. Motors have lessened the demand for mine mules, sugar mules, loggers, construction, city drayers and farm mules. The demand has narrowed down largely to a farm mule capable of doing medium farm work. More thought, therefore, must be given to the type of mare and type of jack used, otherwise a lot of misfits will be produced which will not pay cost of production. A foundation herd of 24 jennets and 2 jacks was established. The foundation animals were difficult to locate at this time and were selected to represent different types popular with jack men.

PRODUCTION OF MEDIUM WEIGHT FARM HORSES THROUGH BREEDING AND FEEDING. Byron H. Good and Ralph S. Hudson, *Michigan Agricultural Experiment Station.*

During the winter of 1943–44, three angles of this project were emphasized. 1. Twelve rising three-year-olds were fed in the open at hay stacks instead of hay scattered on the ground as in the previous winter as two-year-olds. Their average weight on November 17, 1942 was 1202.5 and 1397.9 pounds when taken to the barn for breaking to harness in the spring of 1944. From Morgan crossbreds to Belgian geldings the range in weight at the last weighing

was 1,180 to 1,760. 2. Ten rising two-year-olds which had grain as weanlings were wintered on hay stacks with the coming three-year-olds, and five fillies of the same approximate age and breeding were wintered at the barn and full fed on grain and hay. The colts in the field weighed 1,257 pounds November 22, 1943 and averaged 1,235 pounds May 18, 1944. Those wintered at the barn on grain weighed on the same dates 1,302 pounds and 1,324 pounds, not enough difference to begin to justify the extra cost of grain, shelter and chore labor. 3. Twelve weanlings, draft and cross bred Arabs, were carried on winter pasture and hay stacks while twelve others of similar breeding were fed full grain and hay rations in individual box stalls at the barn. The first group weighed 664.01 pounds, November 15, 1943 and eleven of the number (one died with influenza) averaged 683.06 April 17, 1944. Those at the barn averaged 721.6 pounds on November 15th and 932.9 on March 17, 1944. The last group consumed 8 pounds of grain per head daily consisting of 6 pounds of oats and 2 pounds of ear corn with 9 pounds of hay.

EVIDENCE FOR THE NON-ESSENTIALITY OF NICOTINIC ACID IN THE DIET OF THE HORSE. P. B. Pearson, R. W. Luecke and H. Schmidt, *Texas Agricultural Experiment Station.*

Shetland ponies were used to determine whether or not nicotinic acid is a dietary essential for equine. They were fed rations that provided approximately 0.10, 0.25 and 0.5 mg. of nicotinic acid per kg. of body weight daily. The growth performance of the ponies was virtually the same on the three levels of nicotinic acid intake. Weanling ponies were fed a ration that provided 0.10 mg. of nicotinic acid per kg. of body weight daily for a period of 36 weeks. During this period the ponies made satisfactory gains in weight. Balance studies were made whereby the intake and outgo of nicotinic acid in both the feces and urine were measured. On a low nicotinic acid intake the ponies were in a negative balance. The results show that if the horse requires a dietary source of nicotinic acid that it is extremely low, and affords evidence that this vitamin is synthesized in the body of the horse.

Meat Section

J. M. Ramsbottom, *Chairman*

RANCIDITY CONTROL IN CURED MEATS. D. E. Brady, F. H. Smith and R. E. Comstock, *North Carolina Agricultural Experiment Station.*

In a study of rancidity control in cured meats the following antioxidants have been investigated: (1) .02 percent nordihydroguaiaretic acid (N.D.G.A.). (2) .06 percent isoascorbyl palmitate, .06 per cent soya lecithin, and .1 percent mixed tacopherols. (3) .05 percent gossypol. (4) .10 percent gossypol. (5) .20 percent gossypol. (6) .40 percent gossypol. (7) .80 percent gossypol. (8) .01 percent octyl thiopropionate (du Pont antioxidant). These antioxidants were used in various hydrogenated and non-hydrogenated oils. Variables studied also included the effect of light, temperature, smoking and length of storage period. Peroxide values, Hydroxylamine indexes and palatability tests were used to measure rancidity development. All of the antioxidants were in effect retarding rancidity. Smoking and storing in the dark enhanced the effectiveness of the various antioxidants. The efficiency of the various levels of gossypol was directly correlated with concentration. Gossypol used in a concentration of 0.8 percent was particularly effective as an antioxidant.

MEAT COOKERY, PAST, PRESENT AND FUTURE. Jessie Alice Cline and R. C. Pollock, *National Livestock and Meat Board.*

The Cooperative Meat Investigations inaugurated in 1925 to determine the factors influencing quality and palatability in meat, opened up a field of far-reaching possibilities in experimental cookery. To cook cuts for palatability tests in production studies, standard cookery methods were developed. Since the beginning of this study, over 30,000 cuts of beef, veal, pork and lamb have been cooked experimentally and results measured. The meat thermometer

has been developed as a method of controlling degree of doneness. Mechanical devices for measuring juiciness and tenderness of meat have been perfected. The need for studies in the field of quantity meat cookery to consider factors not involved in small quantity cookery was responsible for launching such a study in 1942 at the University of Texas. In all meat cookery investigations, many tests have shown the value of low temperatures over high temperatures for reducing shrinkage losses and in providing meat that is more tender, more juicy and more uniformly cooked than when high temperature is used. Recent research has been concerned with the effect of cooking on the nutritional value of meat. Studies have shown that large proportions of various B vitamins are retained in cooked meat, especially if drippings and gravy are served. Looking to the future it is anticipated that much frozen meat will be available to customers. To determine the best methods of thawing and cooking frozen meats, a study has been launched at Iowa State College sponsored by the Board.

FACTORS AND PROCESSES INFLUENCING THE KEEPING QUALITY OF BACON. D. A. Greenwood, J. E. Stritar, and H. R. Kraybill, *American Meat Institute, The University of Chicago.*

The study included a chemical and microbiological examination of bacon at different stages of processing from the storage of the green bellies immediately after the slaughter of the animals until it was cooked and ready for eating tests. Studies were made on sides from 44 hogs. During storage of green bellies for 6 months at 0–5° F. the peroxide and free fatty acid values increased from nil to 2.6 millequivalents per kg. of fat, and from 0.2 to 0.5 percent respectively. There was no bacterial growth at these temperatures. Good bacon was made from these green bellies. Curing and smoking caused no increase in peroxide values and an insignificant increase in free fatty acids. Microbial counts decreased during smoking. Storage at low temperature (0°–5° F.) prevented the development of high peroxide and free fatty acid values in bacon. The development of free fatty acids could be correlated directly with microbial growth at temperature ranges of 40–50° F., and 70–95° F. Added moldicides and antioxidants were effective in varying degrees in preventing microbial growth and associated development of peroxides and free fatty acids. Of the moldicides, a sealed carton containing carbon dioxide was most effective. Calcium propionate prevented deterioration of the bacon but only in concentrations which made the product inedible. A number of antioxidants retarded development of peroxides but not of free fatty acids.

SOME OBJECTIVE INDICES OF CARCASS GRADE IN MEAT ANIMALS. O. G. Hankins and F. J. Beard, *U. S. Department of Agriculture and War Food Administration.*

The place and value of commercial grading of livestock and meats in the United States system of food distribution is widely understood and appreciated. During a period of about 17 years the United States Department of Agriculture has developed and applied a method which takes into account conformation, finish, and evidences of quality. The need for more definite characterization of grades, especially for dressed carcasses, and of more precise methods for determining differences is recognized. Designed to meet these needs, studies on more than 500 lambs have shown certain weights, measurements and composition values to be highly useful factors for estimating grade of carcass. For example, the relation between width and grade was represented by the correlation coefficient of +0.83 and between edible meat content of rib cut and carcass grade it was +0.88. Similar research on beef, with live weight and feeding constant and little variation in age of the animals, also showed close relationships between a number of measurable factors and carcass grade as determined subjectively. When live weight and other characteristics varied widely, in a group of approximately 325 cattle, the same measurable factors appeared to have less value for estimating grade. However, length in relation to width of body, for example, was promising for that purpose. Limited studies involving objective measures of conformation and finish have demonstrated that clarification and specificity can be given to definition of grades of meat and, indirectly, to those of livestock.

THE COMPARATIVE TENDERNESS OF REPRESENTATIVE BEEF MUSCLES. J. M. Ramsbottom, E. J. Strandine, and C. H. Koonz, *Swift & Company.*

Representative muscles were dissected from "U. S. Good" beef carcasses for the purpose of determining the comparative tenderness of the muscles. Tenderness was determined by (1) shearing the raw and cooked muscles, (2) organoleptic tests on the cooked muscles, and (3) histological examination of the muscles for collagenous and elastic fibers. The results indicate that: (1) there is variation in tenderness in different regions of the same muscle; (2) there is a variation in tenderness of different muscles within standard commercial cuts; (3) most muscles become less tender on being quick heated to 175° F.; (4) there is a correlation between the shear readings and the amounts of collagen and elastin in the muscle; (5) there is a correlation between the organoleptic tests and the amount of collagen and elastin in the muscle.

CURRENT TRENDS IN THE FROZEN FOOD LOCKER INDUSTRY. K. F. Warner, *United States Department of Agriculture.*

Behind the barrier of wartime priority restrictions, the surge to expand the frozen food industry is building up like flood waters behind a dam. Well over a million and a half families are enjoying home-raised locally frozen food from the 5,300 locker plants now operating in 48 States. The thousands of commercial outlets for quick frozen food are pouring another near billion pounds of frozen food onto the family dinner table annually. Adapting frozen food to the needs of the various homes, communities and sections, and to nationwide distribution requires a perspective, judgment and experience that we are just beginning to acquire. Among the problems to be solved are: (1) Maintaining quality through selection of foods proper processing methods and the use of the right refrigeration equipment. (2) Keeping the cost below the luxury level. (3) Adapting both methods and equipment to local needs. (4) Fitting freezing into the food industry as a partner rather than as a replacement. One thing is sure. In 10 years most of us will look back and wonder why we did not have the imagination to foresee the course that freezing food has taken.

DOES THE NITRITE CURE IMPAIR THE LYSINE VALUE OF PORK? O. H. M. Wilder and H. R. Kraybill, *American Meat Institute, The University of Chicago.*

The question has been raised as to whether the nitrite curing process impairs the lysine value of pork. A representative batch of ground pork was obtained and divided into three parts. One part was frozen as fresh meat, a second part was canned, and a third part was cured and then canned. Both of the canned lots were heat processed by the commercial method used in the packing plant. The three lots of meat were fed to rats as supplements to a basal ration composed chiefly of corn but including added minerals, vitamins, cystine, and tryptophane. This basal ration permits only poor growth unless lysine is added, when good growth results. The total feed was limited to 10 grams daily, and the three meats were fed at three levels, 0.5, 1.0, and 1.5 grams daily. Growth curves for the rats on the three meats at comparable levels indicate that there was no significant difference in food value between any of the three meats, indicating that there was no significant change in lysine content during the curing and cooking process.

Nutrition Section

R. C. Miller, *Chairman*

ANIMAL PRODUCTS IN THE ARMY DIET. George H. Berryman, *Sanitary Corps, U. S. Army.*

Analysis of the food habits of the soldier indicates that animal products play a major role in providing the nutrients required to maintain physical efficiency and strength. The percentage of daily nutrients prescribed May 1941–April 1942 for Field Ration A indicate this great importance of animal products, in terms of food delivered to the mess. These percentages are met to the following extents (in percents) by animal products: Calories—42, Protein—63,

Fat—75, Carbohydrates—6, Ca—68, P—61, Fe—47, Vitamin A—40, Thiamine—56, Riboflavin—72, Nicotinic acid—68, Ascorbic acid—5. The primary aim in the proper feeding of the soldier must remain the conservation of the nutrients contained in this food so well chosen. By emphasizing proper storage, preparation, and cooking, not only will maximum retention of nutrients be favored, but palatability and acceptability will be likewise enhanced. The net result will be optimal nutrition with minimal waste of food.

THE EFFECT OF THE FINENESS OF GRINDING OF OATS ON THEIR DIGESTIBILITY BY AND THE FEEDING VALUE FOR SWINE. E. W. Crampton, *McGill University.*

Three easily distinguishable modulus of ground oats were fed with a protein-mineral-vitamin supplement to nine pigs in three replications. Digestion trials were conducted firstly on 50 lb. pigs on each of the rations and again after a growth period of 60 days. Data are presented to show the effect on digestibility of fineness of grinding on the various fractions of the feedingstuff. The variations in digestibility are related to the amount of refused feed on the two coarser modulus oats and to the liveweight gains of the animals. Growth curves over the 60 day period indicate that more rapid gains are promoted by the finer grinding, the difference in daily gain on fine modulus being nearly twice that on coarse modulus.

THE BIOLOGICAL AVAILABILITY OF SOME DEFLUORINATED, NATURAL AND SYNTHETIC PHOSPHATES. N. R. Ellis and C. A. Cabell, *United States Department of Agriculture.*

Because of inadequate supplies of bonemeals and other phosphates suited for animal feeding, governmental agencies and private interests have expanded facilities for the manufacture of defluorinated phosphates and have investigated various natural products. The biological availability of various experimental and commercially available products has been tested by means of rat-feeding tests in which growth, blood phosphorus, and bone ash have been used as criteria. Samples of defluorinated superphosphates obtained during 1943 showed that none of them were fully equal to bonemeal and some were relatively ineffective in promoting bone formation. Defluorinated rock phosphates such as produced by the T.V.A. proved to be very good products. Tests on several forms of ortho-, meta-, and pyro-calcium phosphates suggested that temperature of defluorination probably was a critical factor in the availability to the animal organism. Tests on experimental batches of superphosphates defluorinated at temperatures of 600°, 760° and 1010° C. showed a wide range in the feeding value, ranging from relatively poor in the case of the lowest and intermediate temperatures to very good for the highest. Several natural phosphates containing considerable iron or aluminum were also relatively unsatisfactory, presumably because these elements render the phosphorus unavailable.

THE RELATION OF THIAMIN IN THE RATION OF THE HOG TO THE AMOUNT OF THIAMIN AND RIBOFLAVIN DEPOSITED IN THE TISSUE. M. E. Ensminger, W. W. Heinemann, T. J. Cunha, and E. C. McCulloch, *State College of Washington.*

A three year study with natural and synthetic rations has been completed using 14 groups of pigs fed different levels of thiamin. A modification of the paired feeding technique was employed to control feed consumption. Synthetic rations were fed which contained (1) No thiamin, (2) 0.10, (3) 0.19, (4) 0.42, (5) 0.51 and (6) 1.02 mgm thiamin daily per kilogram of body weight. Natural rations were fed with and without animal protein and with levels of thiamin comparable to levels fed in most of the synthetic rations. Fluorometric methods were used to assay for thiamin and riboflavin. Thiamin deposition in the body is directly related to thiamin intake. Analyses on a wet basis show that the thiamin content of pork is greatest in hams and loins followed by shoulders, hearts, livers, sausage, and kidneys. When no thiamin was fed, the deposition of riboflavin in the heart and liver was higher than when thiamin was

included in the ration. Liver, kidney and heart were highest in riboflavin followed by ham, shoulder, loin, and sausage. The bactericidal action of the blood sera of the pigs against *Escherichia coli*, *Salmonella typhimurium*, *Eberthella typhosa*, and *Staphylococcus aureus* did not appear to be influenced by type of diet or thiamin level. Coliform counts of the feces of the pigs receiving synthetic rations, either without thiamin or at different levels of thiamin, were approximately 1000 times higher than the coliform counts of pigs receiving natural rations, suggesting a possible difference in intestinal vitamin synthesis between pigs fed a synthetic as compared to a natural ration.

EFFECT OF VARIOUS LEVELS OF CALCIUM, PHOSPHORUS AND VITAMIN D INTAKE ON BONE GROWTH. Lorin E. Harris, Charles F. Bassett, and C. Ford Wilke, *U. S. Department of the Interior* and *Cornell University*.

In a factorially designed experiment, the effects on bone growth of four levels each of calcium, phosphorus and vitamin D were investigated. One hundred twenty-eight foxes were fed the experimental diets beginning at age of 50 days (weaning time), the animals were killed at age of 254 days (pelting time). During the course of the experiment, observations were recorded on the appearance of gross deficiency symptoms, including lameness, bent and enlarged leg bones, large cranial bones and undershot jaws. X-ray photographs were taken at about 150 days of age. At the close of the experiment the isolated humeri were used to measure total ash, specific gravity, and degree of bending of the bones. Under the conditions of the experiment, vitamin D appeared to have little effect upon bone development. The amounts of calcium and phosphorus in the diet were important, but the calcium: phosphorus ratio showed an even greater influence upon bone growth. The results are discussed with the idea of showing how an experiment of this design can be applied to determine both the requirements for individual nutrients and also their interrelationships. This technique can also be used for other species of animals.

EFFECT OF DIET ON GESTATION AND LACTATION PERFORMANCE. J. L. Krider, B. W. Fairbanks, and W. E. Carroll, *University of Illinois*.

A basal ration composed of ground yellow corn 83 percent, soybean meal (expeller) 8 percent, tankage (60 percent protein) 5 percent, fish meal (Menhaden) 2 percent, limestone 0.5 percent, steamed bone meal 0.5 percent, iodized salt 0.5 percent, and fortified cod-liver oil 0.5 percent, has been fed in drylot to gilts during the growing, gestation, and lactation periods. This ration contained 15.0 percent crude protein, 0.9 percent calcium, 0.6 percent phosphorus, 10 to 40 p.p.m. manganese, 1.17 mg. riboflavin per lb., 10.6 mg. nicotinic acid per lb., and 2.28 mg. pantothenic acid per pound. After farrowing, all gilts were fed the basal ration. The supplements fed during growing and gestation with the percentage of the pigs weaned were as follows: (1) basal ration, 13 percent and 7 percent (two years' work); (2) basal ration plus 6 percent dried corn distillers' solubles, 48 percent; (3) basal ration plus 12 percent dried corn distillers' solubles, 41 percent; (4) basal ration plus 6 synthetic vitamins (thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, and choline), 50 percent; (5) basal ration plus 6 percent dried corn distillers' solubles and 4 percent alfalfa meal, 85 percent; and (6) basal ration plus 10–12 percent alfalfa meal, 83 percent and 82 percent (two years' work). Nearly complete lactation failure resulted when the basal ration was fed during gestation and lactation. The importance of adequate nutrition during gestation and the value of alfalfa meal as a practical source of the water-soluble vitamins is clearly shown by the results of lot 4, which was fed the basal ration following farrow.

VITAMIN A REQUIREMENTS OF CALVES. J. M. Lewis and Logan T. Wilson, *Beth Israel Hospital and The Borden Co.*

Six groups of four calves each were fed various levels of vitamin A, ranging from 32 to 1,024 U.S.P. units per kilogram of body weight per day. These levels were fed for a period of four to eight months. Data were obtained on rate of growth, blood levels of vitamin A,

and liver storage. The results indicate that maximum growth was obtained on an intake of 64 U.S.P. units per kilo of body weight. The concentration of vitamin A in the blood reached maximal levels at an intake of approximately 512 U.S.P. units per kilo. Liver storage was quite variable although, in general, calves receiving 512 units per kilo or below, had quite low liver stores, whereas those receiving 1,024 units per kilo had considerable storage.

VITAMIN A AND VITAMIN C STUDIES ON THE BLOOD PLASMA OF LAMBS. A. L. Pope, P. H. Phillips, and G. Bohstedt, *University of Wisconsin.*

Data on the vitamin A and vitamin C levels of the blood plasma of twelve pregnant ewes were obtained for the purpose of following the normal level of these vitamins in the blood plasma of their lambs. The blood samples of the lambs were analyzed for vitamins A and C before the lamb had nursed, at twenty-four hours of age, four days, seven days, and once a week thereafter. A blood sample of each lamb's dam was taken at the same time and analyzed. The results of the fifteen lambs born indicated that both vitamin A and vitamin C of the blood plasma are low at birth. A higher level of vitamin A appeared in the blood of the lambs at twenty-four hours of age than at four days or one week. Vitamin C tended to reach a normal level more rapidly than vitamin A. The vitamin A blood level of the ewes was lower at parturition and twenty-four hours afterward than during pregnancy or lactation.

THE RIBOFLAVIN CONTENT OF SOYBEANS AS DETERMINED BY THE RAT GROWTH METHOD IN A LATTICE SQUARE DESIGN. F. W. Sherwood, R. E. Comstock and J. O. Halverson, *North Carolina Agricultural Experiment Station.*

Previous experience has shown that the assay for riboflavin in soybeans by the rat-growth method yields higher and much more variable results than those obtained by the photofluorometric method. Since a lattice square design offered distinct possibilities for reducing the experimental error, it was used in comparing nine diets. These comparisons were planned to give as precise a riboflavin assay as possible and also to see whether or not soybeans contain certain possible growth stimulants, not in the basal ration, which would be measured as riboflavin. The results show that the lattice square was 35 percent more efficient than a randomized block design with the same number of replications. In addition, equal replication of this experiment would have required three times as many experimental animals in the latter type of design. Thus, in studies to which the lattice square technique is applicable, it will yield equal or greater efficiency with many less animals. The data also show that when protein, fat, fiber, minerals and cod liver oil are approximately equal in all diets, and all rats receive daily equal and adequate amounts of thiamine, pyridoxin and calcium pantothenate, there is no stimulation of growth caused by the addition of choline, p-aminobenzoic acid, cystine, α tocopherol and 2 methyl 1,4-naphthoquinone. The sample of Tokyo soybeans assayed was found to contain 6.0 mcgm riboflavin per gram, a value which is approximately twice that found by the photofluorometric method. The difference in results obtained by these two techniques cannot reasonably be attributed to chance.

THE USE OF THIOUREA IN THE FATTENING OF MEAT ANIMALS. C. W Turner, E. P. Reineke and A. B. Schultze, *Missouri Agricultural Experiment Station.*

It has been discovered recently that the formation of thyroxine by the thyroid gland can be inhibited by the administration of thiourea and related compounds. Thus without surgical intervention animals comparable to those thyroidectomized can be produced. The remarkable increase in the daily gain in weight of steers following thyroidectomy shown by Andrews and Bullard of the Purdue Station suggest the possibilities in the use of these compounds in rations of fattening animals. In preliminary experiments, it became necessary to determine the most satisfactory route of administration, the dosage necessary for inhibition of the thyroid, the time required to obtain the most desirable condition of the carcass, etc. Since we are not in a position to determine the value of these compounds in all types of meat animals it was thought desirable to present a progress report at this time.

In 8 to 10 week-old chickens, the feeding of 0.1 to 0.2 percent of thiouracil in the ration for 2 to 4 weeks caused marked improvement in the amount of fat on the carcass and in tests caused the up-grading of the experimental lots from ½ to ⅓. Thiourea has been used with ruminant animals. Comparison of subcutaneous injection with oral administration indicates definitely that oral administration is to be preferred. In two month old goat kids and lambs .3 to .4 gm. of thiourea caused the thyroids to increase 4 to 5 times in size. On a 100 lb. weight basis from ¾ to ¼ gm. per day are suggested for sheep, goats and calves. This could be mixed into the fattening ration in suitable proportions in relation to their feed consumption. The time and dosage required to obtain the best finished carcass has not been determined. (Mo. Exp. Sta. Jour. Series No. 959).

Pasture and Range Section

R. H. Lush, *Chairman*

THE EFFECTS OF SEVERAL VARIABLES ON THE DIGESTIBILITY OF SOME COMMON PASTURE FORAGES BY STEERS.

W. P. Garrigus, *Kentucky Agricultural Experiment Station.*

Forty-nine digestion trials have been completed with western Hereford feeder steers ranging in weight from 481 pounds to 794 pounds. These digestion trials consisted of a 5-day preliminary period and an 8-day collection period. Fecal collections were made with the aid of a steer harness and sack similar to that described in Illinois Bulletin 454. The dry-matter intake for each steer was held constant throughout the 15-day period through the aid of the electric quick-drier described by Reed in the 1937 A.S.A.P. proceedings, pages 354–361. Wheat, Rosen rye, Balbo rye, Kentucky No. 1 barley, Italian rye grass, Koren lespedeza, and bluegrass were cut at different stages of maturity and fed in their fresh condition in amounts to furnish the pre-determined intake of dry matter. No satisfactory correlation was discovered between the digestion coefficients for dry matter of two steers on one forage compared to corresponding of coefficients for the same two steers on other forages. Advancing maturity in the different species resulted in a variable decline in digestibility of dry matter.

VARIATION IN DETERMINATIONS OF DIGESTIVE CAPACITY OF SHEEP.

Ernest Browning Forbes, Ralph F. Elliott and Raymond W. Swift, *Pennsylvania State College.*

A study of variation in determinations of digestive capacity in 22 sheep, especially as affecting the number of animals required on each experimental treatment, led to the following observations: The standard errors of determinations with 1, 5 and 10 sheep were, for total digestible nutrients, 0.89, 0.40 and 0.28 pounds per 100, respectively; for digestible protein 1.95 percent, 0.87 percent and 0.62 percent, respectively; and for metabolizable energy 51, 23 and 16 calories, respectively, per kilogram of dry matter. The standard errors of results for 5 sheep were less than half as great as for one sheep; and the standard errors for 10 sheep were about three-fourths as great as for 5 sheep. The decrease in standard error resulting from the use of 10 sheep rather than 5 sheep, therefore, would not justify the added labor and expense. These values represent sheep which had been treated with anthelmintics, and equipment and procedures which provided perfect collection of excreta.

THE MONTHLY PROTEIN AND PHOSPHORUS CONTENTS OF TWO IMPORTANT RANGE GRASSES OF SOUTHERN NEW MEXICO.

W. E. Watkins and J. H. Knox, *New Mexico College of Agriculture and Mechanic Arts.*

Over a period of 96 months, the monthly protein and phosphorus contents are given for two important range grasses, Mesa dropseed (*Sporobolus flexuosus*) and black grama (*Bouteloua eriopoda*). These grasses grew at an altitude of approximately 4200 feet, where 50 percent of the annual precipitation of 9.3 inches usually falls in July, August, and September. This is the season of most rapid growth, which generally matures before the first frost date, about October 25. Black grama contained an average of 7.04 percent protein and .10 percent phos-

phorus during the months of July, August, September, and October. Mesa dropseed contained an average of 8.18 percent protein and .12 percent phosphorus during the same months. These grasses usually lost from 31 to 49 percent of this protein by the following March. Leaching from unusually heavy winter rainfall may cause losses of from 49 to 74 percent of the protein over this period. Black grama lost an average of 49 percent of its phosphorus while mesa dropseed lost 69 percent between fall and the following March. Judging from the grasses analyzed, minimum phosphorus requirements for nonlactating cattle as used by this Station, are not fully met except for a short period at the peak of the growing season. The low protein and phosphorus contents of the grasses in late winter and early spring may be supplemented by the appearance of palatable weeds when favorable moisture conditions occur.

RELATIONSHIP OF INITIAL WEIGHTS TO GAINS OF STEERS ON PASTURE. G. O. Mott. *Purdue Agricultural Experiment Station.*

The relationship between the weights of yearling and 2-year old steers in the spring and the gains made during the grazing season with pasture as the sole ration has been studied during the past three years. A correlation coefficient of −0.09 indicates that less than one percent of the variation in gains made by steers on pasture was accounted for by their weights at the beginning of the grazing season. This study was made with 214 steers used in pasture experiments which included several management treatments on permanent pastures and investigations with various rotation pasture mixtures. For each additional pound of initial weight there was 0.0721 pound less gain during the pasture season. This regression of gain on initial weight did not deviate significantly from zero.

An analysis of the limited amount of data shows that the amount of forage consumed by livestock on pasture is very closely associated with basal metabolism. It appears that the quantity of forage consumed on a given type of pasture is a constant value in relation to the maintenance requirement, remaining at the same level above or below the maintenance requirement irrespective of the weight of steers involved. The same relationship would not be expected with mature animals. It follows that the heavier the steer the greater will be the forage used for maintenance in percentage of that which is consumed.

Sheep and Wool Section

R. F. Miller, *Chairman*

CALCIUM AND PHOSPHORUS REQUIREMENTS FOR EWES. W. M. Beeson, *Idaho Agricultural Experiment Station.*

This paper includes recommendations on the calcium and phosphorus requirements of ewes based on a review of the research studies pertinent to this question. Most of the phosphorus requirements are based on studies conducted at the Idaho Agricultural Experiment Station. Calcium deficiency is not likely to occur in ewes unless they are being fed heavily on grain or grain by-products in combination with non-legume roughage, or non-legume roughage that is low in calcium. Ewes receiving legume roughage as a principal part of their diet will ingest sufficient calcium. Rations containing 0.11 percent calcium (air dry basis) were insufficient for ewes for normal reproduction and lactation. A calcium deficiency may be corrected by adding 1 percent of some suitable mineral such as ground limestone to the grain mixture. Research studies have shown that a ewe will receive ample calcium if the ration (90 percent dry matter) contains the following amounts: 0.16 percent for dry ewes, 0.18 for pregnant ewes and 0.23 for lactating ewes. Ewe rations are more likely to be deficient in phosphorus than calcium because many domestic roughages and range forages are low in this element Aphosphorosis occurred in ewes under farm or range conditions when the ration contained 0.11 percent or less phosphorus on an air dry basis. The phosphorus needs for ewes may be considered adequate, if the ration (90 percent dry matter) contains the following amounts of phosphorus: 0.16 percent for dry ewes, 0.16 percent for pregnant ewes, and 0.21 percent for lactating ewes.

INFANT MORTALITY IN LAMBS IN RELATION TO NUTRITION OF THE EWE. D. S. Bell, *Ohio Agricultural Experiment Station.*

Infant mortality records on two breeds of sheep used largely in experimental winter feeding tests, covering the 10-year period from 1935 to 1944, inclusive, have been classified to show the cause of infant mortality in lambs and analyzed to show the significance of such mortality to the interpretation of experimental results. Of the 820 lambs born to the 653 Merino ewes involved, 124, or 15.12 percent, failed to reach the age of 2 months. During the same period, 656 Shropshire ewes gave birth to 882 offspring of which 204, or 23.12 percent, failed to reach the age of 2 months. This mortality rate varied, one lot with another, from a low of 10 percent to a high of 40.5 percent, all experiments included. Mortality, which is set up as a table of vital statistics under 12 different headings, was found to have no direct significance in the interpretation of the results of the feeding experiments to which the dams were assigned. Even though 54.8 percent of the Merino lamb mortality and 44.5 percent of the Shropshire lamb mortality is classified under the three headings: "still born," "poor mothering and lack of milk," and "weak and chilled," all of which have the aspect of reflecting nutritional deficiencies in the dams, none of these deaths in the several experiments could be assigned directly as of such origin. The conclusion suggested is that before infant mortality which arises in ewe-feeding experiments can be given significant interpretation, from the standpoint of ewe nutrition, each death must be analyzed for cause.

COMPARISON OF THE YIELDS OF SIDE SAMPLES FROM WEANLING AND YEARLING SHEEP. Cecil T. Blunn and James O. Grandstaff, *United States Departments of Agriculture and Interior Cooperating.*

During a five-year period data were collected on the percent yield of clean wool in side samples, taken at weanling and yearling ages, from the fleeces of 461 crossbred ewes in the flock of the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, N. Mex. The crossbred ewes were produced by mating Romney and Corriedale rams with Navajo ewes. Average yield at weaning age was 73.1 percent, with a standard deviation of 6.3 percent. At yearling age the average yield and standard deviation was 56.4 and 10.0 percent, respectively. From the analysis of variance and covariance, it was found that approximately 5 and 6 percent of the total weanling variance was due to ram and year sources of variation. At yearling age about 40 percent of the total variation was attributed to differences between rams and 41 percent to differences between years. The regression of yearling on weanling yield was highly significant. This means that the yield of the yearling side sample can be predicted from the weanling data. From a practical standpoint, however, further research is needed before applying this procedure in the breeding program. The changes in yield which occur between weaning and yearling age must be related to other fleece characters such as staple length, fiber-diameter, density, and fleece type. The relation between yield and environmental factors including precipitation, wind velocity, soil type, and range cover must also be evaluated.

NUTRITION AND AGE OF SHEEP IN RELATION TO BLOOD CONSTITUENTS. C. L. Cole, F. J. Thorp, Jr., M. J. Miller and J. A. Bivins, *Michigan State College.*

Studies were made on 34 lambs representing 6 different breeds. Blood plasma vitamin C, hemoglobin, red cell counts, white cell counts and differential counts were made. The lambs were born in late February and March. Barn ration consisted of ewes' milk, and a mixture of corn, oats and soybean oil meal was creep fed with free access to alfalfa hay. They were turned to pasture the first week in May. Twenty-four showed a hemoglobin value of less than 10 gms. per 100 cc. of blood and 10 exceeded this value on April 19. On May 24 after being on pasture about 2 weeks 29 had a value of more than 10 and the remaining 5 had increased over the April value. On July 13, 19 lambs were over 10 and 15 under with a lowered mean value from May. In general the red cell count tended to follow the hemoglobin value. The maximum and minimum values were: Apr. 19—10,980,000 to 7,440,000, May 24—12,780,000 to 7,780,000, July 13—13,240,000 to 7,580,000. A great deal of variation was found in the white cell count. Maximum and minimum values were: Apr. 19—19,700 to

3,700, May 24—16,100 to 6,000, July 13—14,000 to 4,050. The vitamin C plasma values in April ranged between .12 and .93 mg. per 100 cc. of blood. In May the range was .15 to .75. The July values were .30 to .77. There tended to be considerably more uniformity between lambs after having been on pasture.

WINTER WHEAT PASTURE FOR BREEDING EWES. Rufus F. Cox, *Kansas State College*.

While winter wheat pasture has been widely used as a part of the winter ration for all classes of farm animals for many years throughout the southern plains states, only in the past few years has it received serious consideration as the exclusive or chief part of the ration. Its importance has been magnified enormously since its high nutritive value has been established through extensive commercial cattle and sheep production. Comparatively little is known regarding its exact nutritive properties, or what causes its value to vary so markedly from one season to another or when grown in different localities. The Kansas Agricultural Experiment Station has accumulated considerable experimental data on wheat pasture as a feed for sheep. However, there is nothing in the usual chemical analyses to explain the sharp fluctuations which occur in the nutritive value of winter wheat pasture. For example, such analyses usually show no appreciable difference in samples grown in widely different localities with radically different soil and climatic conditions. However, the response of livestock often indicates a sharp contrast in the nutritive value of wheat grown in different areas.

Applications of phosphate fertilizer to the soil often cause decided preference of stock for forage grown on such soils, although no chemical differences in the forages are apparent. It has not been definitely proved that this perference is consistently projected in greater gains but there are indications to that effect.

THE INFLUENCE OF LOCATION AND SIZE OF SAMPLE IN PREDICTING WHOLE-FLEECE CLEAN YIELD. Elroy M. Pohle and L. N. Hazel, *United States Department of Agriculture, Dubois, Idaho.*

Fleeces of 20 Rambouillet and 20 Columbia range yearling ewes were halved, one half being scoured intact and the other half being separated into 56 small samples weighing approximately 35 grams each before scouring. The average yield for Rambouillets was 44.2 percent and for Columbias was 48.6 percent. The cleanest wool was found on the neck, followed by that on the shoulder, side and breech. The lowest yielding wool was found on the belly, back and rump. The correlations between yields of the half-fleeces and those of the small samples were highest for the side region and lowest for the belly, back and rump. The average of the 56 correlations for the half-fleece was 0.73 for Rambouillets and 0.79 for Columbias, while that for the 12 samples of the side was 0.82 and 0.85, respectively. The small samples were combined into larger groups to study the effect of sample size upon accuracy in predicting whole-fleece yield. When samples were taken from the most accurate region (the side), the standard errors of estimate for clean yield based on samples weighing 35, 70, 140, 210, and 420 grams were 1.84, 1.58, 1.40, 1.30 and 1.08 percent, respectively, for Rambouillets. The corresponding figures for Columbias were slightly larger because of greater variation in clean yield. From these figures, it is estimated that about 5 percent of the information concerning clean weight of whole-fleeces is lost with samples weighing 35 grams and about 2 per cent with samples weighing 420 grams.

PHENOTHIAZINE AS AN ANTHELMINTIC FOR BREEDING EWES. W. T. S. Thorp and W. L. Henning, *Pennsylvania State College.*

The 1–9 phenothiazine salt mixture has been administered continuously to a group of twenty Merino ewes for the past three years. Weekly parasite egg counts were made on each of these sheep during the grazing season. In the winter they were made each month. Blood counts and hemoglobin determinations were made periodically for the past two years. Ten lambs from the first lambing season and ten from the second have been saved for experimental

studies. These have likewise been kept on the 1–9 phenothiazine and salt mixture. At no time after the start of the experiment was phenothiazine given as a drench. No apparent effect has been observed upon the breeding efficiency of these ewes. A summary of the parasite egg counts and other determinations is given in detail.

THE PREVENTION OF LOSSES FROM THE SO-CALLED STIFF-LAMB DISEASE. J. P. Willman, J. K. Loosli, S. A. Asdell, F. B. Morrison, Peter Olafson and H. D. Hopper, *Cornell University.*

An experiment was conducted with 3 lots each of 24 ewes and their lambs to determine whether or not the stiff-lamb disease would be prevented by feeding supplements of vitamin E to a ration that produces the disease. The ewes in lot I fed the check ration of cull beans (red kidney) and alfalfa hay produced 13 stiff lambs of 27 lambs raised. In 1942–43, 36 of 38 lambs became stiff when raised by ewes fed this ration. The ewes in lot II were fed in addition for three months, beginning February 22, 1944, 24 days before the first lamb was born, 2 doses weekly of 9 ml. per ewe of a 8.25 percent solution of mixed tocopherols in cottonseed oil. Two ml. of this solution were given orally to each lamb in lot II at birth and once a week thereafter. The ewes in lot III received only the beans and alfalfa hay, but the lambs were treated with 2 ml. of an olive-oil solution of 140 mg. alpha-tocopherol acetate. No stiff lambs were produced in these lots. Alternate lambs in lot I which showed symptoms of the disease were treated with the water-soluble disodium salt of d, l-alpha-tocopherol phosphoric acid ester. One hundred mg., dissolved in 5 ml. sterile water, were injected subcutaneously. In 6 of 7 treated lambs the symptoms of the disease disappeared in 7 to 19 days after the first treatment. One stiff lamb showed marked symptoms when 26 days old and died 8 days later, even though 2 treatments were given. Pneumonia and gross lesions in the skeletal muscles were found. Five lambs died in the group of 6 that was not treated. The characteristic stiff-lamb lesions were found upon autopsy. In the group of untreated lambs the one that recovered never showed marked symptoms.

Swine Section

L. L. Madsen, *Chairman*

MILORGANITE AND CATTLE MANURE AS SUPPLEMENTS IN SWINE RATIONS. G. Bohstedt and R. H. Grummer, *University of Wisconsin.*

Part of this work was prompted by wartime needs for protein concentrates and the revelations during the past few years that such materials as urea in the case of ruminants, and cattle manure in the case of pigs or poultry, had definite nutritional values. The material here worked with has never been considered a feed. "Milorganite" is activated sludge from the Milwaukee Sewage Disposal Plant and has been dried to be sold as fertilizer for lawns, golf course fairways, and other special fertilizer purposes. On the dry matter basis it has a nitrogen equivalent of 37.5 percent protein. It contains 6.5 percent fat, 7.0 percent cellulose and because of the effluent from many industrial plants, contains a vast array of mineral elements, including trace elements, but also including 2.4 percent sand, 13.4 percent silt, and 14.4 percent clay. Its content of the vitamin B complex is comparable in a number of respects to dried brewers' yeast, particularly in reference to niacin and pantothenic acid. In a feeding experiment in which "Milorganite" replaced linseed meal in amounts varying from 6 to 18 percent in dry-lot rations for pigs, there was an apparent toxic effect at all levels especially at the higher levels and suggests that if this product has a place in swine rations it should be fed in amounts of less than 6 percent of the ration mixture. Such work is being contemplated. Several trials giving pigs on dry-lot rations free access to cattle manure have been conducted since the initial work reported upon last year and are giving affirmative proof of the supplementary benefit of cattle manure in the degree that dry lot rations are deficient in vitamins as may be supplied by leafy green hay.

HYBRID VIGOR IN FIRST CROSSES BETWEEN INBRED LINES OF SWINE. G. E. Dickerson, Jay L. Lush and C. C. Culbertson, *U. S. Department of Agriculture and Iowa Agricultural Experiment Station.*

First crosses between inbred lines of Poland China were compared with inbreds by the same boar in the Iowa station's project of the Regional Swine Breeding Laboratory. The 28 intra-sire comparisons included 56 inbred litters from 11 lines and 60 linecross litters. These were fall litters from 1942 and 1943. Inbreeding of litters averaged 42 percent for inbreds and 6 percent for linecrosses; inbreeding of dams averaged 34 percent for inbreds and 28 percent for linecrosses. First crosses exceeded inbreds in total weight of litter, the ratio being 1.09 at birth, 1.48 at 21 days, 1.63 at 56 days, and 1.90 at 154 days. The increase was larger in viability than in rate of growth, although the two are related. In litter size, the ratio of crosses to inbreds was 1.09 at birth, 1.40* at 21 days, 1.45* at 56 days and 1.57* at 154 days; in pig weight the ratio was 1.00 at birth, 1.06 at 21 days, 1.13* at 56 days and 1.21** at 154 days (* indicates significance at .05; ** at the .01 level). These first cross litters averaged 7.2 pigs born, 5.3 at 21 days, 5.1 at 56 days, and 4.8 at 154 days; pig weight averaged 2.84 lbs. at birth, 11.7 lbs. at 21 days, 31.7 lbs. at 56 days, and 144 lbs. at 154 days. These results are closely similar to those available on performance of good outbred Poland Chinas. Trials are in progress to measure the additional performance to be gained by mating first cross sows to boars of a third line.

WAXY CORN FOR GROWING AND FATTENING PIGS. L. E. Hanson, *University of Nebraska.*

Waxy corn was compared with non-waxy corn (the common commercial type) as a feed for growing and fattening pigs in drylot. The waxy corn used was higher in crude portein, crude fat, crude fiber, and in ash than the non-waxy corn. When given a choice the pigs preferred the non-waxy corn. However, the data indicate that waxy corn is fully as valuable pound for pound for growing and fattening pigs as non-waxy corn.

THE NATURE OF THE DEFICIENCIES OF AN ALL-PLANT RATION FOR WEANLING PIGS IN DRYLOT. J. L. Krider, B. W. Fairbanks, and W. E. Carroll, *University of Illinois.*

All-plant protein rations have been fed under conditions of continuous drylot feeding, on pasture; and in drylot preceded by pasture (rye) feeding. Different results have been obtained, and it has been difficult to ascribe these differences to the amino acids or to the vitamins of the B_2 complex. The all-plant ration fed in continuous drylot was ground yellow corn 50.5; wheat flour middlings, 15; soybean meal 30.5; fortified cod-liver oil 0.5; limestone 1.0; steamed bone meal 2 and iodized salt 0.5. In this experiment weanling pigs were fed in the drylot to 75 pounds in weight, the following treatments, and the figures in parenthesis following each treatment is the average daily gain per pig: (1) All-plant ration plus 6 synthetic vitamins and 1.5 percent liver extract (AB) fed at the 20 percent protein level (0.92 lbs.); (2) same as (1) fed at the 28 percent protein level (0.69 lbs.); (3) all-plant ration plus 6 synthetic vitamins and 10 percent vitamin—free casein fed at 28 percent protein level (0.85 lbs.); (4) all-plant ration plus 6 synthetic vitamins fed at 28 percent protein ration (0.68 lbs.); (5) all-plant ration plus 10 percent alfalfa meal (0.68 lbs.). A detailed and critical examination of the data and further studies by the paired-feeding technique indicate that the all-plant ration fed was deficient in the B_2 complex.

CROSSING INBRED LINES OF SWINE WITHIN A BREED. W. L. Robison, *Ohio Agricultural Experiment Station.*

Since the fall of 1941 a swine breeding project has been under way in which matings of inbred sires, (1) to inbred dams of the same lines, (2) to inbred dams of different lines, (3) to outbred dams, and (4) to dams produced by crossing two other inbred lines are being compared with matings of unrelated outbred sires and dams. The matings were all within the Duroc

Jersey breed. Although 84 percent as many live inbreds as outbreds were farrowed per litter, only 44 percent as many survived to 180 days of age. The inbreds gained more slowly and required more feed per unit of gain than the outbreds. Of the inbreds, 10.6, and of the outbreds, 1.4 percent showed defects of one kind or another. Litters from inbred dams and by inbred sires of different lines averaged 77 and 85 percent as many living pigs at birth and at 180 days, respectively, as the litters from outbred sires and dams. These line-cross pigs gained faster and made slightly greater gains per unit of feed than the outbred pigs. Thus far mating inbred boars and mating outbred boars to outbred sows have given very similar results. Mating boars of one inbred line to sows produced by crossing two other inbred lines has resulted in more pigs saved per litter to market time, fewer runts, faster gains and greater gains per unit of feed than has mating unrelated outbred boars and sows.

NON GENETIC FACTORS AFFECTING PROLIFICACY IN SWINE. H. A. Stewart, *University of Minnesota.*

Selection for prolificacy in swine would be more effective if a portion of the variability in litter size could be associated with definite measures. Intra line, intra farrow linear and partial regressions of the number of pigs farrowed on age of dam, inbreeding of dam, inbreeding of litter, weight of females at mating, gains made during pregnancy, and body length, all were used to determine the relative importance of each of these measures on the total variation in the number of pigs farrowed at approximately one year of age. Litter size increased with the age of dam, weight at mating, and gains made during pregnancy; decreased with an increase in the inbreeding of the dam; and apparently was unaffected by the inbreeding of the litter. Errors in measurement concealed any association between prolificacy and body length. The effects of age were more severe in the months before 12 than after that age. Age was correlated with weight at 0.60. Age and weight, considered alone, each accounted for about 3 percent of the total variance, together they accounted for 4 percent. Correction for inbreeding of dam accounted for about 0.5 percent. Although gains made during pregnancy accounted for about 2 percent of the variance this measure has no value in selection and the effects or causes of these gains cannot be interpreted from this study. Intra line selection on basis of weight at breeding should be almost as efficient in increasing litter size as the use of age and weight together, and more efficient than age alone.

DISTILLERS' FEED PRODUCTS IN RATIONS FOR GROWING PIGS, R. E. Synold, *Joseph E. Seagram & Sons, Inc., Louisville, Ky.*

Distillers' dried solubles and distillers' dried grains were compared with tankage as a source of protein in rations fed growing pigs in drylot from 30 pounds to approximately 145 pounds. It is evident that the protein of distillers' feed products did not contain all of the essential amino acids at a level required to promote a satisfactory rate of growth. The increased fiber content of the diet containing distillers' dried grains was also a factor hindering satisfactory gains. When distillers' dried solubles were used as a vitamin supplement in diets containing a small quantity of animal protein or all-vegetable protein, practical rations for growing pigs were formulated which produced results equal to the control ration (Wisconsin trio mixture) and at its equivalent costs. In all trials, the concentrates containing the highest percentage of crude protein required less concentrate per 100 pounds of gain; however, about the same quantity of protein was required for all lots per 100 pounds of gain.

CULL PEAS AS A PROTEIN SUPPLEMENT FOR GROWING FATTENING PIGS ON PASTURE. E. J. Warwick, M. E. Ensminger and T. J. Cunha, *State College of Washington.*

Previous work at this station showed that cull peas could be successfully substituted for 40 percent of the grain ration of cattle being fed sweetclover hay, but that the higher protein content of the peas did not make them any more valuable pound for pound than barley in a ration of this kind. The present investigations have to do with the efficiency of cull peas as a protein supplement for growing-fattening pigs on pasture. In 1943, a lot of pigs fed a

protein supplement containing 50 percent cull peas, 20 percent tankage, and 24 percent soybean oil meal, self-fed free choice with a mixture of barley and wheat, gained as rapidly as a similar lot fed a supplement of 50 percent tankage, 25 percent soybean oil meal, and 24 percent linseed oil meal. The lot receiving cull peas used slightly less feed per cwt of gain. In 1944, rations containing cull peas as the only protein supplement on Sudan grass pasture were compared with rations supplemented with (1) a mixture of tankage, soybean oil meal, and linseed oil meal and (2) soybean oil meal alone; both when self-fed free-choice with a mixture of barley and wheat, and when complete mixed rations containing the same components were self-fed. Under these pasture conditions, the cull pea rations promoted growth and fattening at as rapid rates as did the rations containing protein from other sources.

NEWS AND NOTES

The thirty-seventh annual meeting of the American Society of Animal Production is scheduled to be held at the Morrison Hotel in Chicago on December 1 and 2, 1944, with a dinner for the honor guest at the Saddle and Sirloin Club at noon on December 3.

The Nominating Committee, composed of B. A. Trowbridge (Chairman), F. B. Morrison and W. H. Peters has, in accordance with the Constitution, prepared the following slate of officers to be presented to the American Society of Animal Production at its next election of officers:

President: A. D. Weber
Vice-president: F. L. Bentley
W. A. Craft

C. W. McCampbell has retired from his position as head of the animal husbandry department at Kansas State College. He is succeeded by A. D. Weber, who has been a member of the animal husbandry department at Kansas State College since 1924. Dr. McCampbell will continue as a member of the staff.

Ralph Bogart, formerly assistant professor of animal husbandry at the University of Missouri, is now working in cattle breeding for the U. S. Department of the Interior, and is stationed on the San Carlos Indian Reservation, San Carlos, Arizona.

James F. Wilson, professor of animal husbandry, University of California, was given the honorary degree of Doctor of Laws by his alma mater, the University of Wyoming, at the 1944 commencement exercises.

Paul Swaffer, formerly assistant extension animal husbandman, Virginia Extension Service, recently resigned to become associated with the Virginia Livestock Association.

Guy A. McDonald, extension animal husbandman, South Dakota Extension Service resigned June 1 to accept a position with the Sioux Falls Stock Yards Co., and has been succeeded by T. O. Larson, former county agricultural agent in Brookings County, South Dakota.

Don W. Chittenden recently resigned his position with the American Hereford Journal to become eastern field representative of the American Hereford Association.

Frank C. Armer, formerly of the Soil Conservation and Grazing Services, and more recently a major in the armed forces, is the new extension animal husbandman of the Arizona Extension Service.

M. A. McCarty, formerly of Pennsylvania State College, is now a member of the animal husbandry staff, Washington State College.

Dale Snodgrass, formerly assistant extension animal husbandman, North Carolina Extension Service, is now livestock manager for the United States Sugar Corporation at Clewiston, Florida.

H. B. Osland is now manager of the Pollock Hereford Ranch, near Sacramento, California.

Robert M. Denhardt, formerly secretary, the American Quarter Horse Association and member of the staff of the Texas Agricultural and Mechanical College, has returned from Brazil, where he has been on a special assignment for the Department of State.

S. R. Johnson, associate professor in animal husbandry, University of Arkansas, has been granted military leave.

A. C. Allen, manager of 3-R Ranch, is now secretary of the Colorado Wool Growers' Association.

James O. Grandstaff has succeeded J. M. Cooper as director of the Southwestern Range and Sheep Breeding Laboratory at Fort Wingate, New Mexico.

Al Severson, formerly of the animal husbandry staff at North Dakota, is now fieldman for the American Hampshire Swine Association.

Herman C. Aaberg, a graduate of Iowa State College, has been made manager of the new livestock department of the American Farm Bureau Federation.

Ray H. Thalman is now manager of St. Francis Ranch at Willitts, California.

W. O. Fraser, assistant chief, Livestock and Meats Branch, Office of Distribution, WFA, resigned in June to accept a position with Wilson and Company, Chicago.

M. T. Foster has been appointed livestock advisor to the Agricultural Attache, United States Embassy, Buenos Aires, Argentina.

Carrol J. Goodell, of the extension staff, Mississippi State College, recently resigned and is now on the staff of the Shorthorn World, Aurora, Illinois.

C. R. Kyd, assistant extension animal husbandman, University of Missouri, has resigned and is now in the United States Army.

The special conference of extension livestock specialists of the North Central region held in Chicago, August 14–15, was attended by representatives from all 12 States and 10 Federal workers.

A conference of livestock workers from the Mid-South was held in Memphis, August 9–10, with an attendance of 21 persons.

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